TM 5-315

WAR DEPARTMENT TECHNICAL MANUAL

FIRE PROTECTION BY TROOP ORGANIZATIONS IN THEATERS OF OPERATIONS

WAR DEPARTMENT • 23 MARCH 1944

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The Adjutant General.

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As prescribed in par. 9*a*, FM 21–b; T of Opns (12); Corps (6); Island Comd (6); Base Comd (6); Def Comd (6); Base Hqs (4); Post, Camp and Sta, Continental U. S. (Fire Dept) (3); Sv C (100); IC 5 (5).

IC 5: T/O & E 5–337, Firefighting Platoon; 5–500, Engr Co (Composite).

(For explanation of symbols see FM 21–6.)

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CONTENTS

CHAPTER 1

GENERAL

1. PURPOSE. This manual provides the essential basic information for training engineer fire-fighting platoons, engineer aviation fire-fighting platoons, and other troop units activated for the purpose of providing suitable fire prevention and fire fighting at military establishments in theaters of operations where other organized forms of fire protection are not available. Except as information may be pertinent or useful, this manual does not apply to the organization, equipment, supplies, or maintenance of fire prevention and fire protection at posts, camps, or stations in the continental United States, or within service commands, defense commands, or departments where this function is performed as a post administrative responsibility in accordance with the provisions of AR 100–80.

2. SCOPE. This manual does not represent the entire training of engineer troops for this purpose or include all essential information pertinent to the evaluation of fire hazards. It does include the organization, training, equipment, and assignment of fire-fighting platoons; planning of fire protection requirements; tactics and technique of military fire fighting; operation and care of fire-fighting tools and equipment; elementary chemistry of fire; hydraulics as related to fire-fighting equipment; fire-prevention principles and practices; and passive air defense of typical military establishments. Sample problems illustrate the use of various formulas given in the text.

3. FIRE PROTECTION, GENERAL. a. Promotion of maximum fire-prevention practices and maintenance of minimum requirements for suitable fire protection are necessary to insure continuity of training operation and a uniform flow of essential supplies and matériel in and from the zone of the interior. In theaters of operations, where the line of supply has been extended long distances and where the potential and probable loss increases with proximity to actual combat, this need

becomes more pronounced. Failure to supply adequate means for fire protection may result in the loss of valuable supplies, matériel, or personnel; and may determine the success or failure of a mission.

b. Fire protection begins with the initial planning of a mission or the lay-out of a camp, progresses through the construction stage, becomes paramount during the period of operation or activation, and continues until the project is abandoned. The basic method and tactics of all fire-fighting troop units are the same, but the problems in the field vary with types of troop units available, combat conditions, water supply, and replacement or maintenance supplies. Under field conditions, even completely equipped and perfectly trained organizations require a maximum of resourcefulness, ingenuity, and improvisation.

4. ZONE OF THE INTERIOR. a. Fire protection for military installations in the zone of the interior is normally a post administrative function under the responsibility of a post engineer or other authorized officer on the staff of the post or installation commander, as provided in AR 100–80. In most instances, protection is given by civilian type organizations, similar to a municipal fire department composed either of all civilian or part civilian and part military personnel.

b. Under some circumstances, engineer fire-fighting units may be assigned as temporary auxiliaries to the regularly organized post fire force during intervals between completion of their specialized training and embarkation for an active theater. When so assigned, engineer fire-fighting platoons will be governed by post regulations and practices as they apply to the regular post organization. Under such circumstances, adequate water supply, complete planning of the scheme of protection, and a full complement of personnel and equipment normally may be expected. Since disturbance of normal routine by enemy aerial attack or by ground forces' activities is not normally expected, fire protection in the zone of the interior closely parallels a civil function of comparable size or character.

5. THEATER OF OPERATIONS. In the theater of operations, civilian fire forces are not available and dependence must be placed on fire-fighting platoons or other troops detailed to fire-protection duty. Fire protection in active theaters of operation is made more difficult by enemy air raids, artillery fire, sabotage, failure of civilian fire protection in occupied metropolitan areas, and blackout requirements. Fire-fighting units must be well trained and well equipped to provide fire protection under such difficulties. Commanders of fire-fighting units must be prepared to advise higher commanders on passive air-defense plans and to assist in training auxiliary fire fighters.

CHAPTER 2

ENGINEER FIRE-FIGHTING ORGANIZATIONS

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6. TRAINING AND EQUIPMENT. Fire-fighting platoons are provided for both air and ground forces, and are equipped and trained to meet the specific requirements peculiar to their respective operations. The platoon is a trained nucleus around which normal fire defense, including both preventive and protective measures, and fire-defense phases of passive defense may be built.

7. MISSION. The mission of fire-fighting platoons is to—

Develop plans to insure adequate fire protection.
Organize and carry out fire-prevention measures.
Extinguish fires in an assigned area.
Perform rescue operations in connection with fires.
Train auxiliary fire fighters.
Maintain fire-fighting equipment.
Support other fire-fighting units if necessary.
Advise higher commanders on minimum safety requirements in the lay-out of new installations.
Advise higher commanders on passive air-defense measures.

8. ENGINEER SERVICE ORGANIZATION. Personnel and equipment allowances for the fire-fighting section are included in T/O & E 5–500. Included are provisions for a section headquarters administrative unit, a fire truck or crash truck fire-fighting unit, and a fire trailer or crash trailer fire-fighting unit, with aggregate personnel allowance of two, nine, and six for the respective units. In the total personnel allowance for this section, provision is made for a commissioned section commander, fire chief, section chiefs, clerk, fire fighters, pump operators, and truck drivers. Complete fire-protection units are composed of any combination of fire-fighting units according to the nature and needs of the assignment. Provision is made in T/O & E 5–500 for supporting mess, repair, supply, and maintenance teams to be attached to or with

fire fighting sections in the engineer service organization as needed. Equipment for each of the designated types of section is identical with the equivalent section as described for the more fixed types of engineer fire-fighting platoons or engineer aviation fire-fighting platoons covered in paragraphs 9 and 10.

9. ARMY SERVICE FORCES PLATOON. a. Organization. The fire-fighting platoon of the Army Service Forces consists of a headquarters section and three fire-fighting sections. Besides functioning as a normal platoon headquarters, the headquarters section has personnel and equipment for fire fighting. Included in its personnel are the platoon leader, a fire chief, a section chief, fire fighters, a pump operator, and drivers for light vehicles. Each fire-fighting section consists of a section chief, fire fighters, a pump operator, and a truck driver.

b. Equipment. This organization is equipped primarily for structural fire fighting in such ground installations as depots, hospitals, wharves, docks, bases, and cantonments. In theaters of operation, the various sections are dispersed to protect the entire area involved and to avoid disruption to service from any single bomb hit.

(1) The headquarters section has one class 325 oversea type fire truck (figs. 1 and 2). The pumping unit is a front-mounted centrifugal pump capable of pumping 300 gallons per minute at 120 pounds pump pressure. Other equipment mounted on the truck includes a 300-gallon tank, two side-mounted reels with 150 feet of ¾-inch booster hose each, a 24-foot extension ladder, a 12-foot roof ladder, and miscellaneous fire-fighting tools. The hose bed has a capacity of 600 feet of 2½-inch and 400 feet of 1½-inch fire hose.

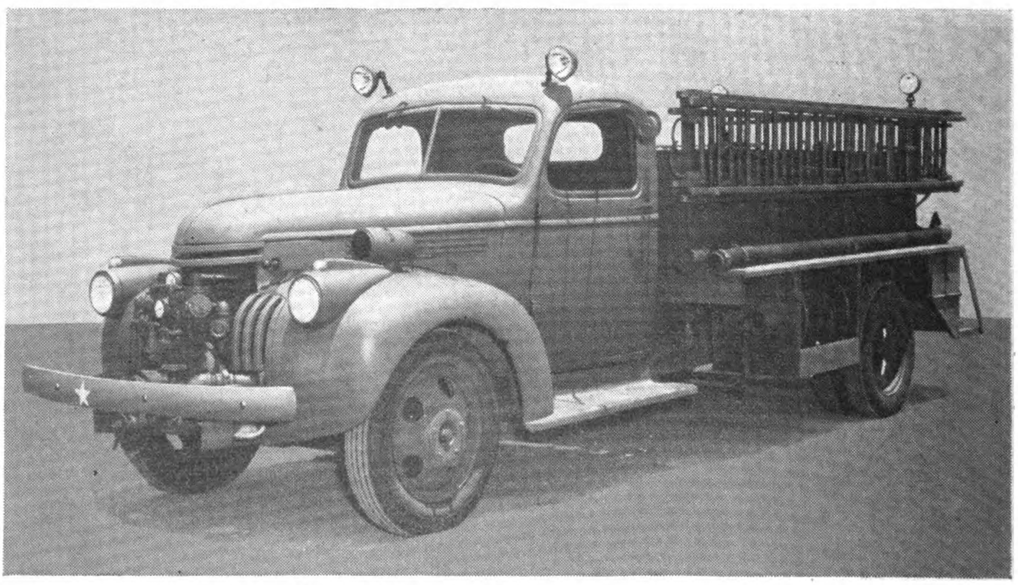


Figure 1. Class 325 oversea type fire truck—left-front view.

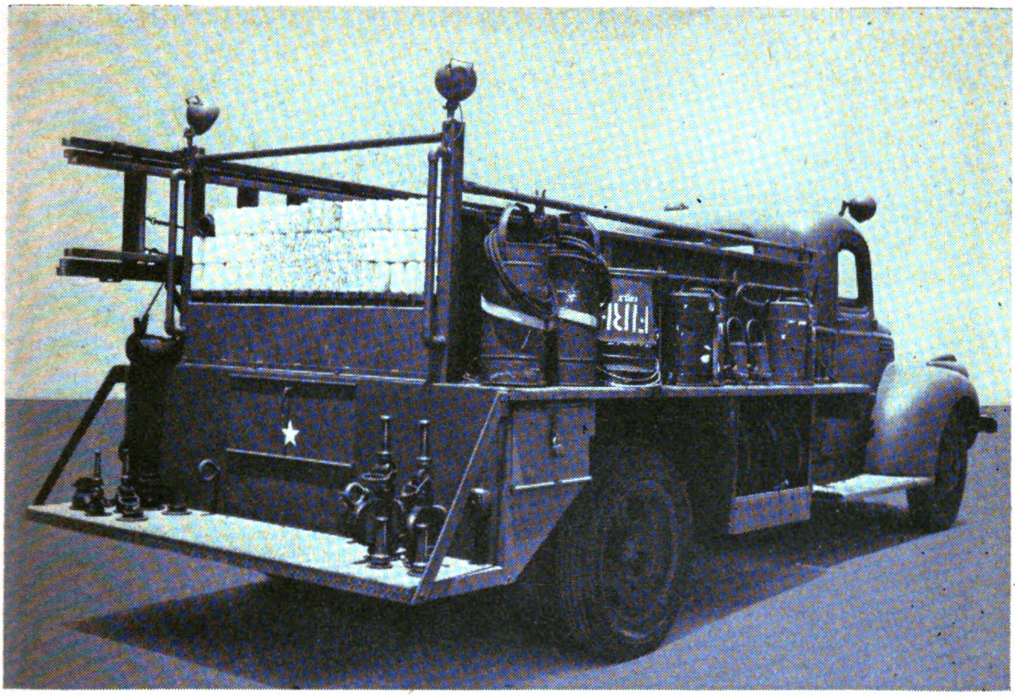


Figure 2. Class 325 oversea type fire truck—right-rear view.

(2) Each fire-fighting section has one class 1000 pumper trailer towed by a 1½- or ¾-ton vehicle (figs. 3 and 4). This unit consists of a gasoline engine-driven centrifugal pump capable of pumping 500 gallons per minute at 120 pounds pump pressure, mounted on a standard 1-ton cargo trailer. The hose bed has a normal capacity of 700 feet of 2½-inch fire hose and 300 feet of 1½-inch fire hose. Additional hose and equipment capacity is provided in the weapons carrier, which serves also to transport the fire-fighting personnel.

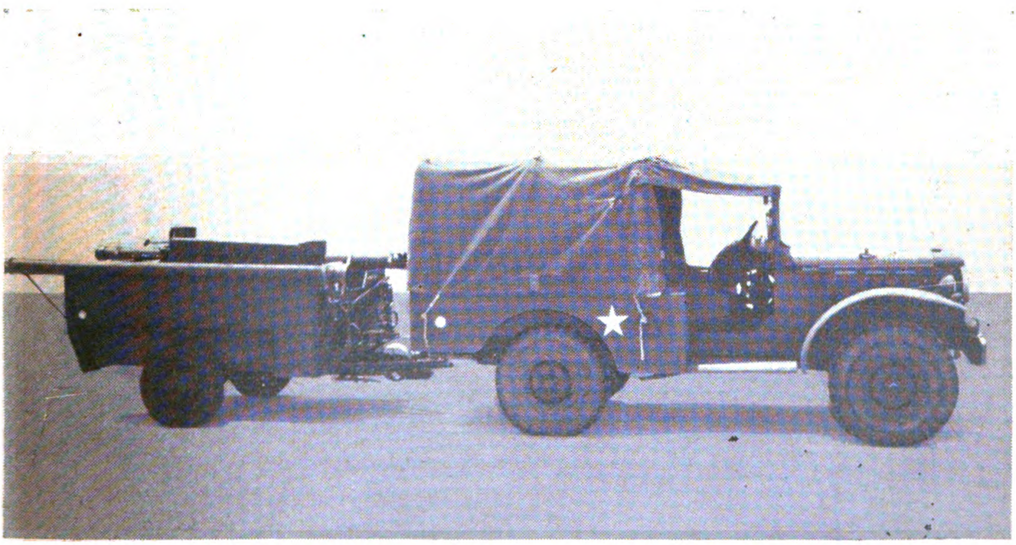


Figure 3. Class 1000 pumper trailer—right-side view.

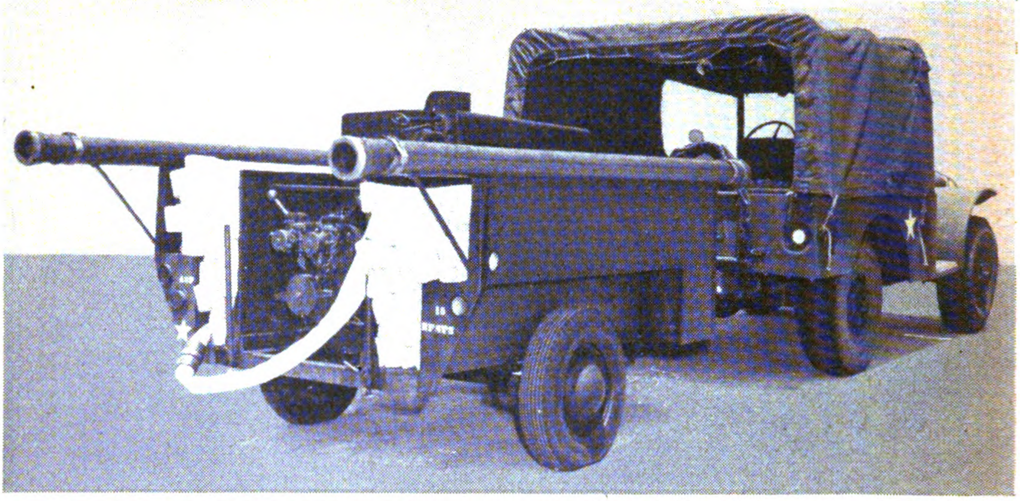


Figure 4. Class 1000 pumper trailer—right-rear view.

c. Transportation. Transportation consists of a ¼-ton truck, a ¾-ton weapon carrier, and three 1½-ton trucks or ¾-ton weapons carriers for towing fire trailers in addition to carrying personnel and equipment.

d. Armament. The only weapons assigned the platoon are caliber .30 carbines.

10. ARMY AIR FORCES PLATOON. a. Organization. The fire-fighting platoon assigned to Army Air Forces is identical in organization with that assigned Army Service Forces, but differs from these platoons in equipment and training to meet the specialized requirements of Army Air Forces assignment.

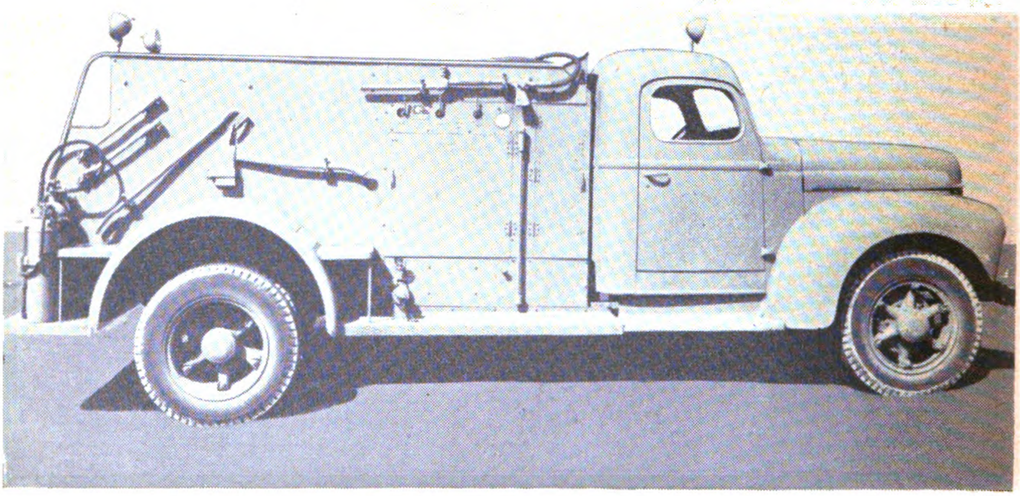


Figure 5. Class 125 crash truck—right-side view.

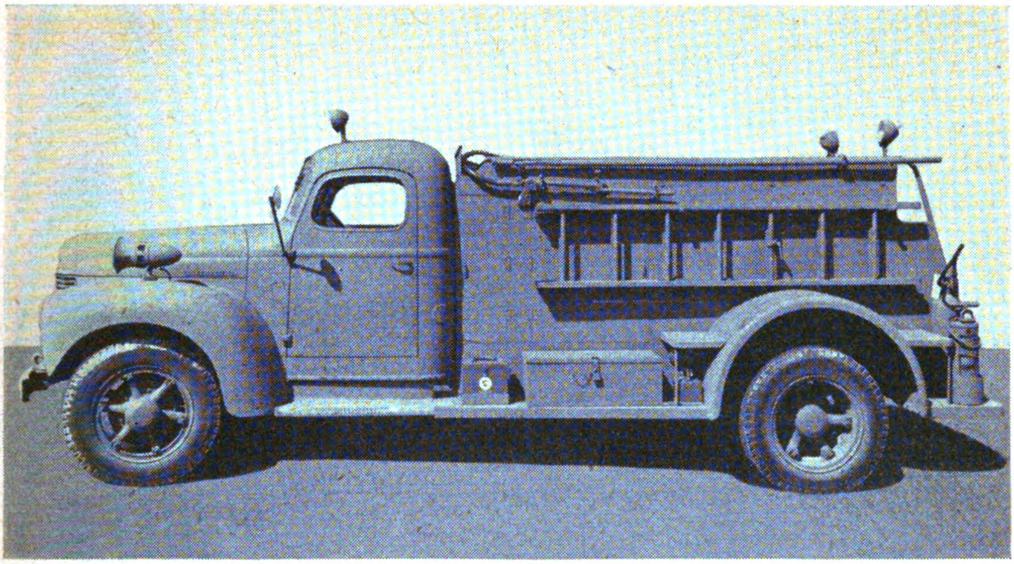


Figure 6.—Class 125 crash truck—left-side view.

b. Equipment. The platoon headquarters section has one class 125 or class 135 crash fire truck (figs. 5, 6, 7 and 8).

(1) The class 125 crash truck has a midship-mounted, high-pressure piston pump which delivers 55 to 60 gallons per minute at 600 to 800 pounds pump pressure. The truck also carries a 300-gallon tank, three basket type reels, with 100 feet of ¾-inch high-pressure hose each, a 16-foot folding ladder, a crash kit, and miscellaneous crash fire-fighting equipment.

(2) The class 135 crash truck has a front-mounted, semihigh-pressure, centrifugal pump capable of pumping 60 gallons per minute at 350 pounds pump pressure. Other equipment on the truck includes a 300-gallon tank, two side reels and one rear reel with 100 feet of 1-inch extra heavy booster hose each, a 16-foot folding ladder, a crash kit, fire extinguishers, and small fire-fighting tools.

(3) For information on the class 150 and 155 crash fire trucks see TM 5-316.

(4) Two sections have class 1010 or class 1020 crash trailers (fig. 9). The class 1010 crash trailer consists of a high-pressure piston pump with a capacity of 35 gallons per minute at 750 pounds pressure, mounted on a two-wheel trailer which has in addition a 150-gallon tank, two bracket type hose reels with 100 feet of ¾-inch high pressure hose each, a crash kit, and fog and foam apparatus. The bed of the towing vehicle is used to carry fire extinguishers, tools, and men. The class 1020 crash trailer differs from the class 1010 trailer in that it has a semihigh-pressure centrifugal pump, with a capacity of 100 gallons per minute at 500 pounds pump pressure, and has two reels with 100 feet of ¾-inch heavy booster hose each.

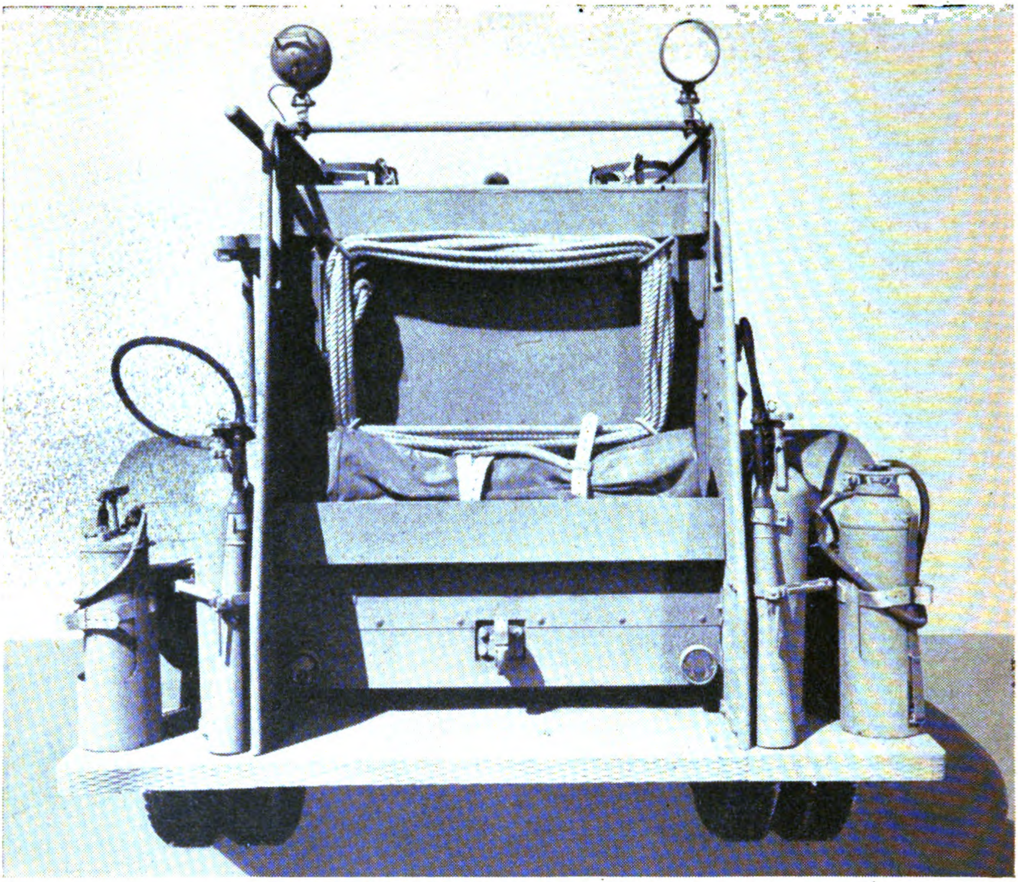


Figure 7.—Class 125 crash truck—rear view.

(5) The third section has a class 1000 pumper trailer, described in paragraph 9b (2).

(6) The headquarters section, and two sections, are equipped primarily for crash fire fighting. The third section is equipped and trained for structural fires.

c. Transportation and armament of the fire-fighting platoon assigned the Army Air Forces are identical with those of similar units serving ground organizations.

11. ASSIGNMENT TO ARMY SERVICE FORCES. a. General. The assignment of fire-fighting platoons to active theaters of operations depends upon the troop population, the nature of the activity involved, the value of the buildings and matériel, and their relative value to the operation involved.

b. Cantonments. The normal assignment of fire-fighting platoons is on the basis of one platoon for each 50,000 of population or major fraction thereof. At dispersed cantonment installations, sections may be distributed approximately as follows:

Population	*Type of quarters* *Barracks*	*Tents*
50,000	1 platoon	1 platoon or 3 sections
25,000	3 sections	2 sections
10,000	2 sections	1 section
5,000	1 section	1 section or none

c. Depot and storage. Normally, one fire-fighting platoon is assigned each depot, port, or other storage installation with a total storage area of two million square feet with distribution as follows:

Storage area (square feet)	*Buildings*	*Open storage*
2,000,000	1 platoon	3 sections
1,000,000	3 sections	2 sections
500,000	2 sections	1 section
100,000 to 500,000	1 section	1 section or none

d. Hospitals. Sections of ground platoons are assigned to protect hospital areas. The number depends upon the type, location, and dispersion of the hospital and its proximity to other protected facilities nearby. The following may be used as a basis:

Number of hospital beds	*Isolated*	*Not isolated*
1,000	3 sections	2 sections
500	2 sections	1 section

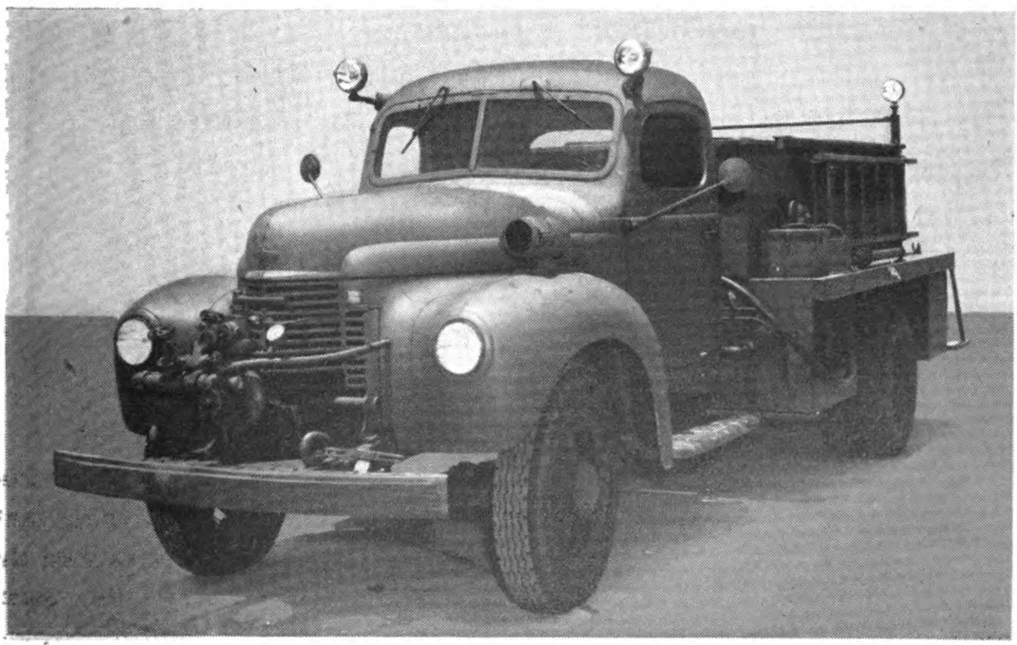


Figure 8.—Class 135 crash truck—left-front view.

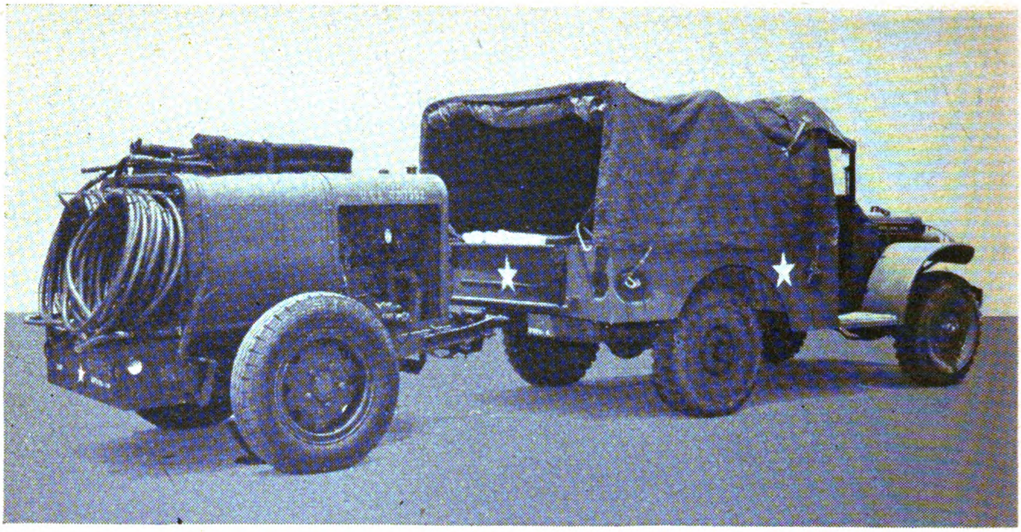


Figure 9. Class 1010 crash trailer—right-rear view.

12. ASSIGNMENT TO AIR FORCE INSTALLATIONS. The engineer aviation fire-fighting platoon is designed to service an air group, and is assigned on the basis of one section per air squadron. However, in an active theater located in a combat zone, requirements depend upon the activity of the field and its susceptibility to enemy attack. In deciding such requirements, the following must be considered:

a. Type of airplanes in use.

(1) Light bombers or fighter craft.

(2) Medium and heavy bombers.

(3) Transport and cargo planes.

b. Amount and location of gasoline.

c. Amount, kind, and location of bombs and ammunition.

d. Paint shops, hangars, barracks, and administrative buildings.

e. Location of field with respect to active combat.

f. Mission of the air group.

g. Amount of air traffic.

h. Repair practices.

If an airfield is located near enough to an active theater for its airplanes to engage in combat and other operations, every ship is a potential crash, both upon take-off and landing. Any ship returning from active combat has been exposed to damage. At such fields, rescue operations are the first duty of the fire sections. Gasoline fires, tank explosions, and ammunition and bomb explosions may complicate the fire-fighting operations. Since such fires spread rapidly, the rescue operation requires at least one section. Successful fire control requires not less than one additional section. The crash truck and trailers

normally are located on the field near the field operations control facilities. During periods of heavy flying activity additional crash equipment is placed near the runways to cover all potential crash areas. The third section, being equipped for structural fire fighting, is located near the building area and adjacent to the field.

CHAPTER 3

USE AND CARE OF EQUIPMENT

SECTION I
FIRE PUMPS

13. PRINCIPLES OF PUMPING. a. General. Pressure is the energy which moves water through a hose or pipe line to distant or elevated places, overcomes the retarding effects of friction in the hose line, raises the water to the desired height, and provides the necessary velocity of discharge at the nozzle.

b. Supply of water to the pump. Water can be supplied to a pump by two general methods: by connecting the pump to a source under static or other pressure, for example, a tank or hydrant; or by suction lift or drafting from ground water sources. The pressure method is self-evident; discussion will be confined to the supply of water by drafting.

c. Suction lift. A suction lift is made by creating a partial vacuum inside the pump so as to exhaust the air from within the pump and the suction hose attached to it. This reduces the effective pressure in the system below the normal atmospheric pressure acting upon the surface of the water in which the suction hose is immersed. As a result, the atmospheric pressure on the surface of the body of water forces the water to rise in the hose, eventually filling the pump.

d. Limits of suction lift. (1) For practical purposes, it may be assumed that water is incompressible and occupies a constant volume. Therefore a given weight of water will always occupy the same space, and a given volume of water will always have the same weight. A column of water 1 square inch in cross-sectional area and 1 foot high weighs 0.43 pound, and 1 pound of water fills the same tube to a height of 2.3 feet.

(2) The tube C–1 (fig. 10) has a cross-sectional area of 1 square inch. When the open end is immersed in a body of water (B–1) and a vacuum pump is attached near the closed end and the air exhausted, a

vacuum is created within the tube. Meanwhile the atmospheric pressure on the surface of the water is transmitted through the water to the mouth of the tube, for it is a characteristic property of liquids and gases that a pressure executed at any point is transmitted equally in all directions. Normal atmospheric pressure at sea level is 14.7 pounds per square inch. Hence, since the tube has a cross-sectional area of 1 square inch, the total force acting upward at the mouth of the tube is 14.7 times 1, or 14.7 pounds. There being no weight or pressure in the tube to counteract this force, the water will rise in C–1 until the weight of the water supported in the column is equal to the force at the mouth of the column. Since 1 pound of water will fill the column to a height of 2.3 feet, 14.7 pounds will fill it to a height of 14.7 times 2.3, or approximately 34 feet. This is the maximum theoretical height to which it is possible to lift water by suction.

(3) That this limit also holds true for any size tube with vertical sides is emphasized by reference to tube C–2 in figure 10. This tube has a cross-sectional area of 6 square inches. Following the same reasoning used in examining tube C–1, we find there is a pressure of 14.7 pounds per square inch pressing upward at the mouth of the tube. The area of the mouth of the tube being 6 inches, the total force at this point is 6 times 14.7, or 88.6 pounds. A column of water weighing 88.6 pounds is six times as heavy as the one weighing 14.7 pounds; but since the area of C–2 is six times that of C–1, the water in C–2 will rise to the same height as that in C–1.

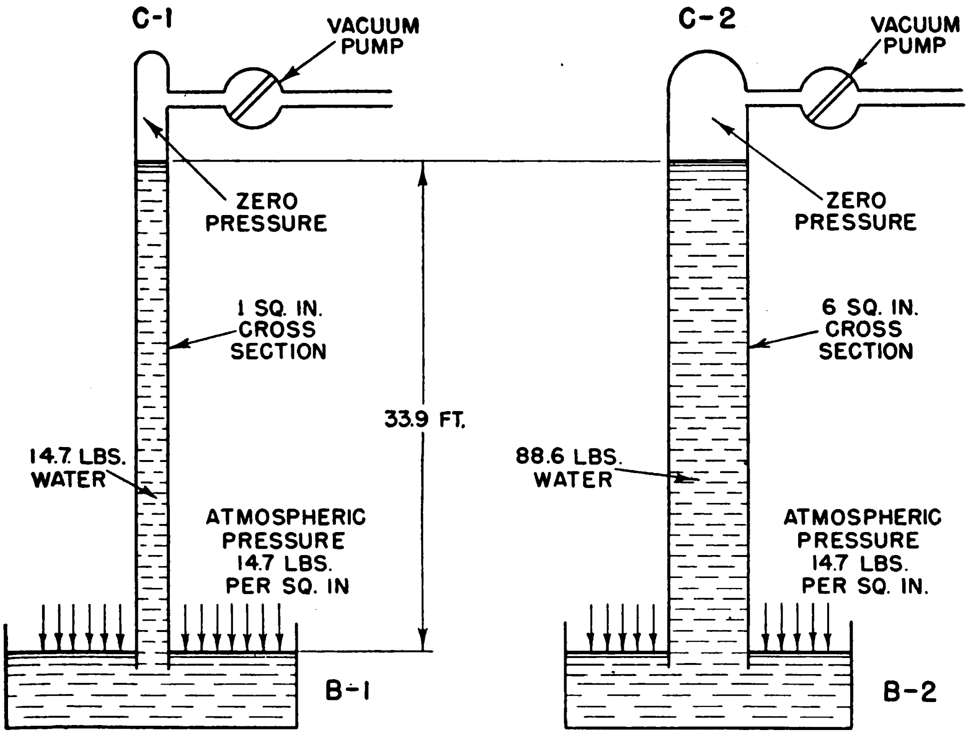


Figure 10. Limit of suction lift for perfect vacuum.

(4) It is impossible to create a perfect vacuum even with the most precise scientific apparatus. Minute air leaks through connections, moving parts, and the frictional resistance of the suction hose reduce the height to which water will rise to from 26 to 28 feet. This maximum is based on ideal conditions. The dependable lift for fire pumps in reasonably good condition is not more than 15 to 20 feet.

e. Effect of atmospheric pressure. As elevation above sea level increases, the atmospheric pressure decreases at a rate of approximately ½ pound for every 1,000 feet of elevation. Consequently the theoretical height to which water may be lifted by suction decreases with the increase in elevation. At 5,000 feet elevation, the atmospheric pressure is about 12.2 pounds per square inch; theoretically water can be lifted to a height of 28 feet. At an elevation of 10,000 feet the atmospheric pressure is about 9.7 pounds, and the theoretical lift is only 22 feet. The actual lift is reduced in proportion to the theoretical one.

f. Effect of air leakage. Even slight leakage of air into the suction side of the pump makes it difficult to exhaust sufficient air from the pump and the suction hose to cause water to rise in the pump. Any appreciable air leakage after the pump has taken suction causes the pump to lose its priming. It is important that gaskets be maintained in good condition and that connections be made airtight to prevent air leaking into the system with a resultant failure of the pump.

14. ARMY FIRE PUMPS. a. Piston or reciprocating pumps. (1) OPERATION. *(a)* The single-action piston pump (fig. 11) consists of a piston (P) which is moved back and forth in the chamber (C) by some external source of power. The flow of water in and out of the chamber is controlled by two valves (X) and (Y) which open in opposite directions. Suction is through a pipe (S) immersed in a water source, and discharge is through another pipe (D).

(b) Figure 11Ⓐ shows the position of the valves during the suction stroke. The movement of the piston (P) away from the valve end of the pump increases the volume of the water space (C). This creates a partial vacuum in the chamber which closes the discharge valve (X) and opens the intake valve (Y). Since the pressure in the chamber is less than the atmospheric pressure acting on the surface of the water in which the suction pipe (S) is immersed, and since the difference in elevation between the pump and the water source is within the limit of suction lift of the pump, water rises through the suction pipe and the intake valve into the pump chamber.

(c) At the end of the suction stroke the piston stops, reverses its direction, and begins the discharge stroke. Figure 11Ⓑ shows the position of the valves during the discharge stroke. When the piston begins to move toward the valve end of the pump the increase in

pressure closes the intake valve (Y) and opens the discharge valve (X). Further travel of the piston forces the water through the discharge valve and out the discharge pipe (D).

(d) After reaching the limit of its movement on the discharge stroke the piston reverses its direction and begins another suction stroke to complete the pumping cycle.

(e) A pulsating flow is delivered by the single-action piston pump since water is being discharged from it during only one-half the pumping cycle. To provide a more uniform flow and greater efficiency many piston pumps are double-acting, that is, valves are provided to permit intake and discharge of water on both sides of the piston, resulting in continuous discharge. The operating principle of the valves is the same as in the single-action pump. Piston pumps are positive displacement pumps; they discharge a definite quantity of water for each complete cycle of the pump.

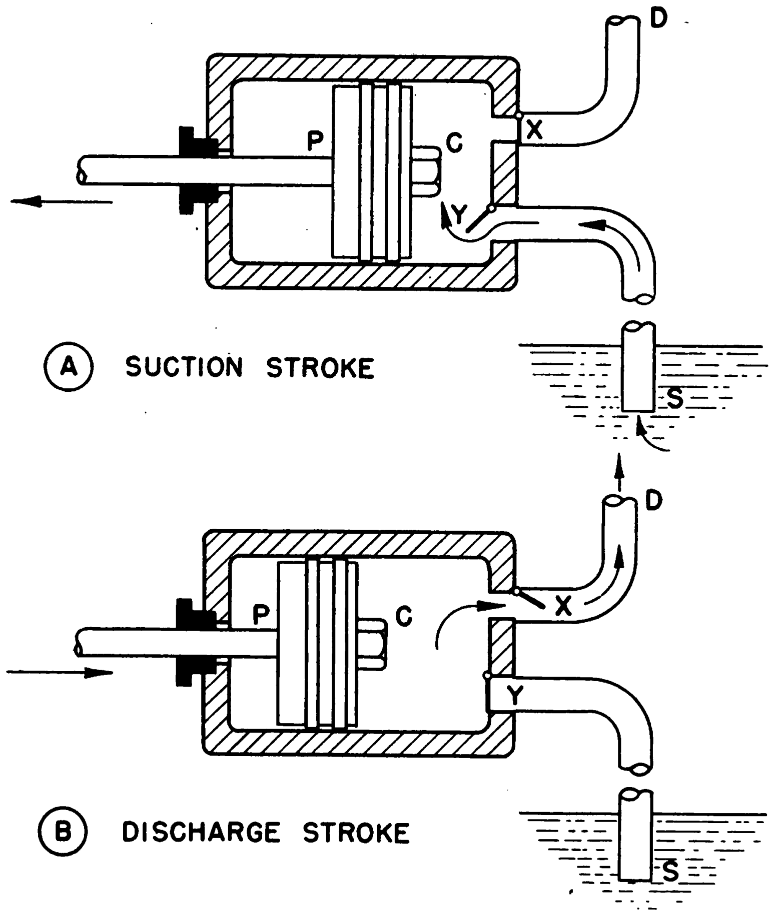


Figure 11.—Piston pump.

(2) CARE AND MAINTENANCE OF PISTON PUMPS. In ordinary operation, piston pumps require little attention. However, they must be properly lubricated. In both lubricating and changing oil follow

the manufacturer's recommendations. A daily inspection is required as a precaution. After use in cold weather, the pump must be drained thoroughly to prevent freezing and consequent bursting of the pump heads. All drain plugs and discharge valves must be opened and allowed to drain and the pump then run empty a few revolutions to expel all water. Bearings must be kept properly fitted and all packing glands and regulator packing kept tight. The suction strainer and screen must be checked after each pumping job.

(3) CHURN VALVE. When the flow of water in the positive displacement pump is stopped by shutting down a hose line, theoretically the pump must be stopped, for the discharge is directly proportional to pump speed. To eliminate the necessity of stopping the pump and to give greater flexibility in its operation, a churn valve (fig. 12) is provided on displacement type pumps. It is simply a manually controlled bypass valve between the suction and discharge sides of the pump. When this valve is opened, water from the discharge side passes into the suction side and provides a constant circulation within the pump, even with all discharge outlets closed.

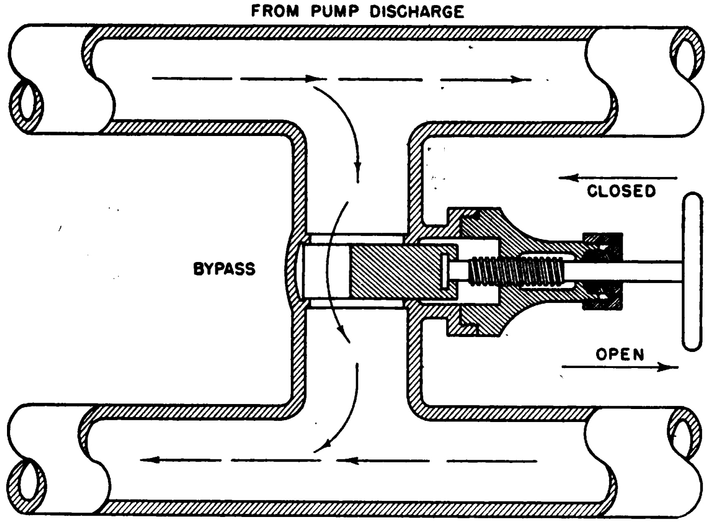


Figure 12. Churn valve.

(4) CARE OF CHURN VALVES. Churn valves should be inspected regularly for proper operation and for packing gland leaks. Replace the packing when necessary.

(5) AUTOMATIC RELIEF VALVE. *(a)* The automatic relief valve is used on displacement pumps. The pump operator seldom knows in advance when a hose line is to be shut off. If a single line is operating from a displacement pump, sudden closing of the line stops the pump before the operator can open the churn valve. Before the pump stops, however, there is a momentary "backing-up" of the pressure in the

pump; and this pressure may be sufficient to blow the hose line off the pump casing or even to injure the motor. If more than one line is operating and some of the lines are suddenly closed, the pump may continue to run as long as one line is in operation; but the pressure built up may be enough to cause sufficient reaction in the nozzle to injure the men holding it. To prevent this, an automatic relief valve is used. There are several different types of automatic relief valves in common use, but all operate upon the same general principles. Briefly, it consists of an arrangement of valves and springs such that when the pressure on the discharge side exceeds the pressure for which the controlling spring is set, the valve is opened, permitting water to flow into the suction side of the pump, thus relieving the discharge pressure. When the pressure drops below the setting of the spring, the valve closes and the flow from discharge to suction side stops.

(b) In a typical arrangement of an automatic relief valve (fig. 13) water from the discharge side of the pump is prevented from flowing into the suction side by a valve (V) blocking the opening between the discharge and suction chambers. This valve (V) is held closed by the discharge pressure. Water under pressure from the discharge side is prevented from flowing through the control line by a valve (v) held closed by the compression of its spring (s). The resistance of the valve (v) to the water pressure may be varied by turning the screw control cap (K). Figure 13 shows the action in the relief valve when the discharge pressure exceeds the pressure at which the compression spring is set. The valve (v) opens permitting water to flow into the chamber (c) and through a connecting tube to chamber (C) of the relief valve proper. Water is held in the chamber (C) by a piston (P), on a common shaft with valve (V), between discharge and suction sides of the pump.

(c) When the valve (v) is opened, the unit pressure acting upon the piston (P) in the chamber (C) is equal to the unit pressure acting upon the valve (V) from the discharge chamber (D). However, the total area of the piston is greater than the area of the valve (V); hence the total force on the piston (P) tending to open the valve is greater than the total force on the valve (V) tending to hold it closed. Consequently the valve (V) opens permitting water to flow from the discharge chamber (D) into the suction chamber (s). When the pump pressure drops below the pressure on the spring, the valve (v) is relieved by allowing the water to drain out through the drain opening. The pump pressure then acting upon the valve (V) in the discharge chamber closes it, stopping the flow between discharge and suction sides of the pump.

(6) CARE OF AUTOMATIC RELIEF VALVES. Some types of relief valves are fairly easy to maintain; others require the services of a

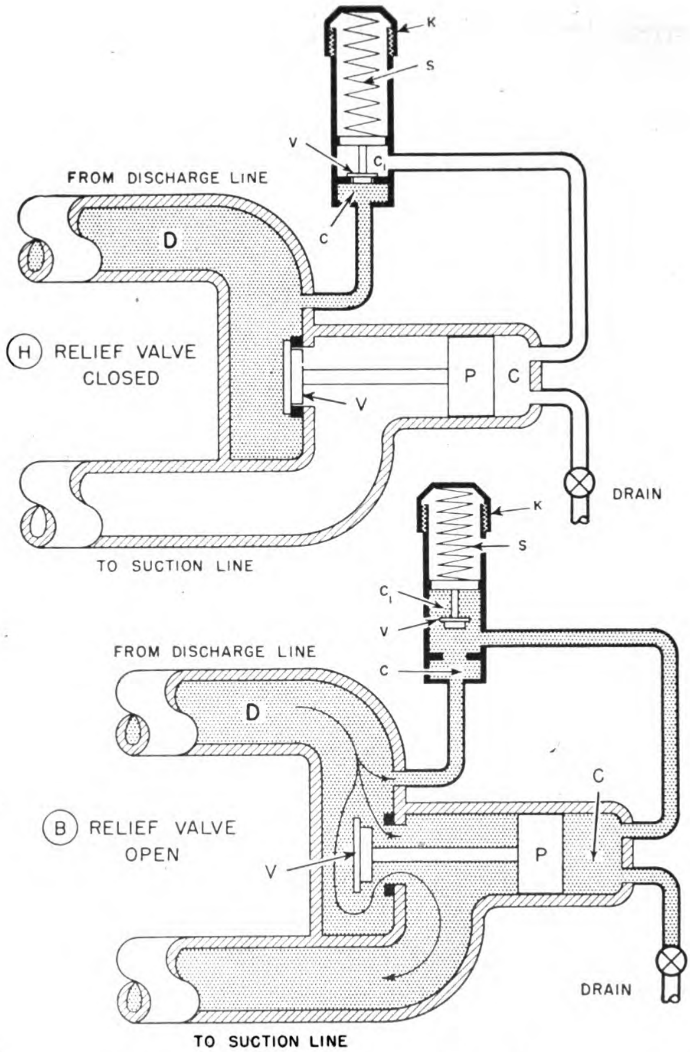


Figure 13. Automatic relief valve.

mechanic. Sand, scale, and other obstructions sometimes get under the valve seat and interrupt operation. When this occurs, if the operator has the tools and has been instructed in the operation, he may unscrew the valve head, remove the stem and spring, and clean out the obstruction. After the cleaning, and before reassembling the valve, he should use lubricating oil on all the parts.

b. Centrifugal pumps. (1) PRINCIPLES. *(a)* The centrifugal pump is not of the positive displacement type; hence there is no definite discharge with each revolution of the pump. Its operation is based upon the principle that a rapidly revolving disk tends to throw water toward the outer edge. A similar action may be demonstrated by swinging a pail of water in a circular motion over the head. The centrifugal action tends to hold the water to the bottom of the pail, so that no water is spilled from the open end of the pail. If a small

hole is cut in the bottom of the pail, the stream of water emerging through this hole gains in velocity and range as the velocity of the pail increases.

(*b*) The single-stage centrifugal pump (fig. 14) consists of a single disklike impeller (1) mounted on a shaft within and usually eccentric to the pump casing (C–C), as shown in figure 14Ⓐ. Figure 14Ⓑ shows the construction of a typical impeller. As the impeller revolves in the direction indicated by the arrow, water introduced through suction (S) enters through the center of the impeller (O), is picked up by curved vanes (V) as they revolve with the impeller, is thrown to the outer edge of the impeller by the centrifugal action and passes through openings (P) into the open space in the casing. Since the circumference of the impeller disk is greater at the outer edge of the bladelike vanes (P) than it is at the inner one (O), the outer edge of the impeller travels faster. Hence the velocity of water is increased as it passes through the impeller from the center (O) outward (P). Likewise, as the rate of rotation of the impeller increases, the velocity with which the water is thrown from the openings (P) into the open casing increases.

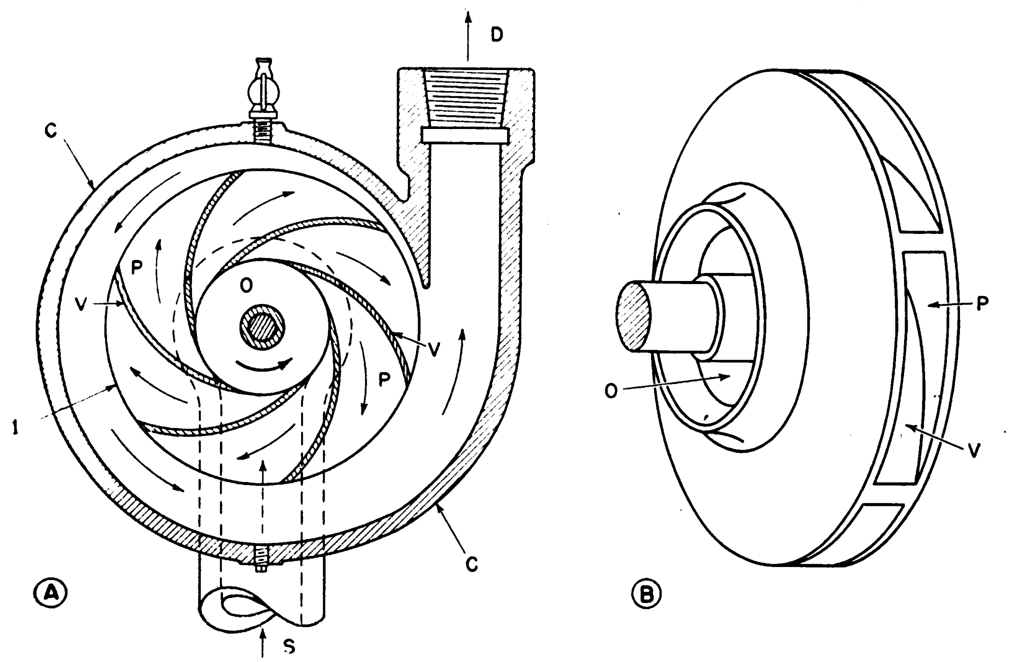


Figure 14. Single-stage centrifugal pump.

(*c*) In most centrifugal pumps the cross-sectional area between the outer edge of the impeller and the wall of the casing increases as it approaches the discharge outlet, forming what is known as a volute. This gradually increasing space is needed since the water is thrown from the impeller around the entire circumference and hence the total quantity of water passing through the casing is increasingly greater

toward the discharge outlet. The volute enables the pump to handle this increasing quantity of water, at the same time permitting the velocity of the water to remain constant or to decrease gradually though maintaining the required discharge. In centrifugal pumps not using the volute principle, the flow of water is directed toward the discharge outlet by a series of stationary diffusion vanes fastened to the inner wall of the pump casing. The rotation of the impeller creates a velocity in the water which is converted into pressure as it approaches the confining space of the discharge pipe. Water under pressure on the discharge side of the casing is prevented from flowing back into the pump by the close fit between the casing and the impeller at the entrance to the suction inlet, by the rapid movement of the impeller, and by the equal pressure in the pump casing.

(d) In the centrifugal pump, there are no valves or other blockades within the pump. A continuous waterway extends through the pump from the suction intake to the discharge outlet. Passageways through the impeller are frequently small, however, and are subject to clogging if foreign matter is permitted to enter the pump. Since such clogging of the impeller seriously affects the operation of the pump, care should be taken that the pump is properly screened.

(e) In the positive displacement pump, quantity discharge is directly proportional to the speed of the pump and the speed has no direct bearing on the pressure developed. When the centrifugal pump is pumping at a constant pressure, its discharge also is directly proportional to its speed. At a constant quantity, its pressure is directly proportional to the square of its speed. The quantity of discharge from a centrifugal pump is related to the speed of the pump and developed pressure in such a way that with quantity, speed, or pressure constant, an increase or decrease in one or the other of the remaining two factors produces a change in the other. For example, within certain limits governed by the design of the pump, with pressure constant, an increase in speed produces an increase in quantity. With quantity constant, an increase in speed produces an increase in pressure. With speed constant, an increase in pressure produces a decrease in quantity. With centrifugal pumps, unlike positive displacement ones, slippage is not a factor. A shut-down of the operating lines causes an increase in pressure and an automatic slippage of 100 percent within the pump but does no damage to pump or motor.

(2) CARE OF CENTRIFUGAL PUMPS. The centrifugal pump is probably the most easily cared for pump in fire service. It should be flushed and cleaned out after pumping dirty water or sea water. However, aside from regular lubrication and packing, little maintenance is required.

(a) Alignment. Anchor bolts must be checked.

(b) Lubrication. Oil should be changed after every fire. Also it must be added to the pump on long pumping jobs. It can be used on the shaft around the packing gland when prime is being made.

(c) Pump transmission. The transmission is cooled by water from the pressure side of the pump. The waterways in all tubing, piping, and connections must be kept open.

(d) Packing gland. Care should be taken to use the recommended size and kind of packing. The packing nut must be tightened evenly but not enough to cause binding.

(e) Pump lever. The pump lever must be kept tight on the shaft.

(f) Suction hose. The suction hose must be checked for missing gaskets and damaged threads.

(g) Strainers. Both the strainer in the pump and that on the suction hose must be kept clean.

(3) PRIMING BY VACUUM. *(a)* In the vacuum method of priming centrifugal pumps, advantage is taken of the vacuum created in the operation of the gasoline motor. The principle is the same as in the operation of a vacuum automobile windshield wiper. When the gasoline motor is operated (fig. 15), the action of the pistons and valve draw air from the intake manifold into the gasoline mixture entering the cylinders. Thus the connection between the intake manifold and the pump casing is subjected to a vacuum which is transmitted to the entire pump assembly and suction hose causing water to rise inside the suction hose and fill the pump.

(b) From figure 15 it can be seen that if the vacuum connection remained open after the pump was primed, water eventually would be drawn through the connection and into the cylinders of the motor. To prevent this possibility, it is necessary to provide some adequate control arrangement whereby the vacuum is shut off instantaneously as soon as the pump is primed. This is generally accomplished by inserting a vacuum chamber in the connection between the motor and the pump. This reservoir traps the water being drawn through the connection. In the two common designs of reservoir, the vacuum supply is shut off by a float-actuated valve when the water reaches a predetermined level in the reservoir, or is controlled by automatic check valves operated by the weight of the water when it reaches a predetermined level. Since with the vacuum type of priming the vacuum is shut off immediately, the pump impeller must be engaged during the priming; otherwise the pump loses its prime as soon as the vacuum supply is shut off. As is true with the windshield wiper, *the most effective vacuum is created at slow speed and with little or no load on the motor.* Many difficulties experienced in priming by this method may be traced directly to excessive speed of the motor.

(c) All connections on vacuum lines between intake manifold and

pump must be tight. See that the supply line is not chafing against any metal and is not too close to the exhaust pipe. Inspect the float and float valves to see that the float is in proper condition and that valves are adjusted and seated properly. Since the water way between suction and discharge sides of centrifugal pumps is completely open, all discharge valves must be closed during priming until the pump is primed and under pressure.

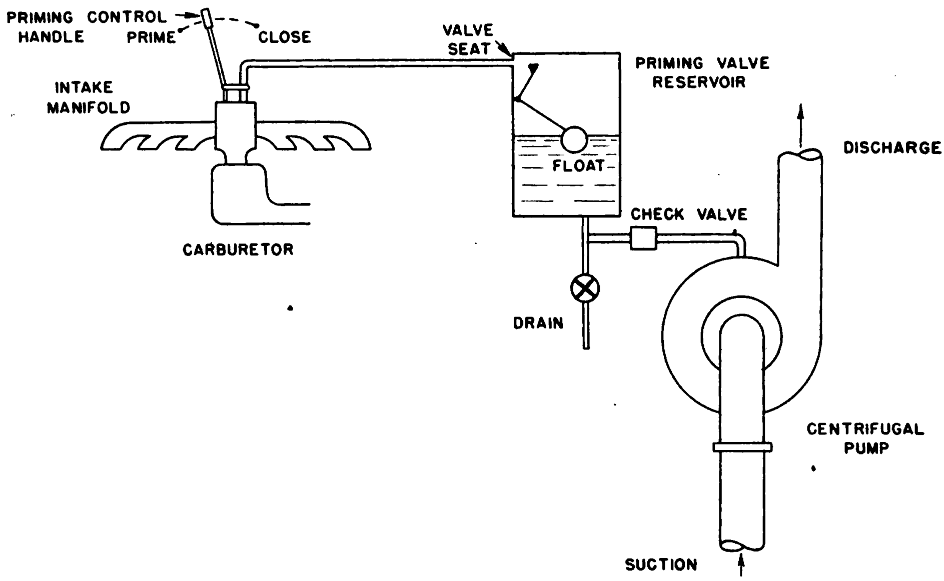


Figure 15. Vacuum priming of centrifugal pumps.

(4) INJECTOR PRIMERS. In class 1000 pumps, the pressure of the gases collected in the exhaust manifold of the gasoline engine is used to create the necessary vacuum to prime the pump. A valved connection to the exhaust manifold permits the exhaust gases to escape through an ejector venturi valve to which a connection also is made from the pump casing. When the control valve is opened, the pressure of the exhaust gases escaping through the venturi causes a suction pull in the connection to the pump and eventually withdraws all of the air from within the casing, thus priming the pump. With this type of priming, discharge valves must remain closed until the pump is under pressure.

15. GAUGES. a. The direct reading gauges at the pump are necessary to keep the operator informed as to the performance of the pump. The gauges register the exact amount of pressure output or input to the pump at the points to which they are attached. Gauges used on fire-department pumping engines, and in practically all mechanical usage other than for special tests and experimental purposes, are of the bourdon type. There are three different kinds of bourdon gauges: the pressure gauge which indicates the amount of positive pressure; the vacuum gauge which indicates the amount of vacuum; and the com-

pound gauge which indicates either the positive pressure or the vacuum, depending upon the conditions at the point at which it is attached. Bourdon gauges are constructed in two types: the single-spring type and the double-spring type. The latter, being more rugged in construction and of greater stability, is the main type used for fire pumps. Figure 16 shows the face markings of the pressure and compound gauges as well as the internal construction of both the single- and double-spring types.

b. All operate upon the same principle. Pressure enters through the threaded gauge-fitting and passes into the bourdon tube or tubes. These are single or double, thin, curved, hollow metal tubes, closed at their upper ends. Pressure inside the tubes tends to straighten them slightly, causing a slight movement in their free upper ends. This movement is multipled by a series of connecting levers and transmitted to a rack and pinion controlling the movement of the indicating hand. A hairspring attached to the pinion shaft holds the assembly together tightly and dampens the movement of the needle. Positive pressure in the bourdon tube causes the needle to move clockwise over the calibrated gauge face. Vacuum in the tubes increases the curvature of the tubes and causes the needle to move in a counterclockwise direction.

c. Pressure gauges are installed on the discharge side of all positive displacement pumps. Vacuum gauges are rarely used on fire-apparatus pumps, but the compound gauge is installed on the suction side of all pumps and usually is used instead of the pressure gauge on the discharge side of centrifugal pumps. The reason for this is that the centrifugal pump normally has a continuous waterway. Hence, when a vacuum is applied to the pump, as during suction, the vacuum is transmitted also to the discharge pressure gauge until the pump is primed. An ordinary pressure gauge is damaged by such a variation from pressure to vacuum.

d. The gauge valve in the connection to the pump should be partly closed until the gauge gives a steady reading without undue vibration. The gauge drains should be opened after the gauge has been used. Bourdon gauges are calibrated and marked by comparison with a standard master gauge or mercury column gauge. They should be tested and recalibrated at frequent intervals by means of a master gauge or a special dead-weight tester.

e. Pressure calibrations are usually marked to denote pounds of pressure per square inch in excess of normal atmospheric pressure; however, some show corresponding feet of head or elevation. Vacuum calibrations are usually indicated in *inches of vacuum.* For practical purposes, 1 inch of mercury is roughly equivalent to 1 foot of water. In determining the amount of work being done by a pump, the differ-

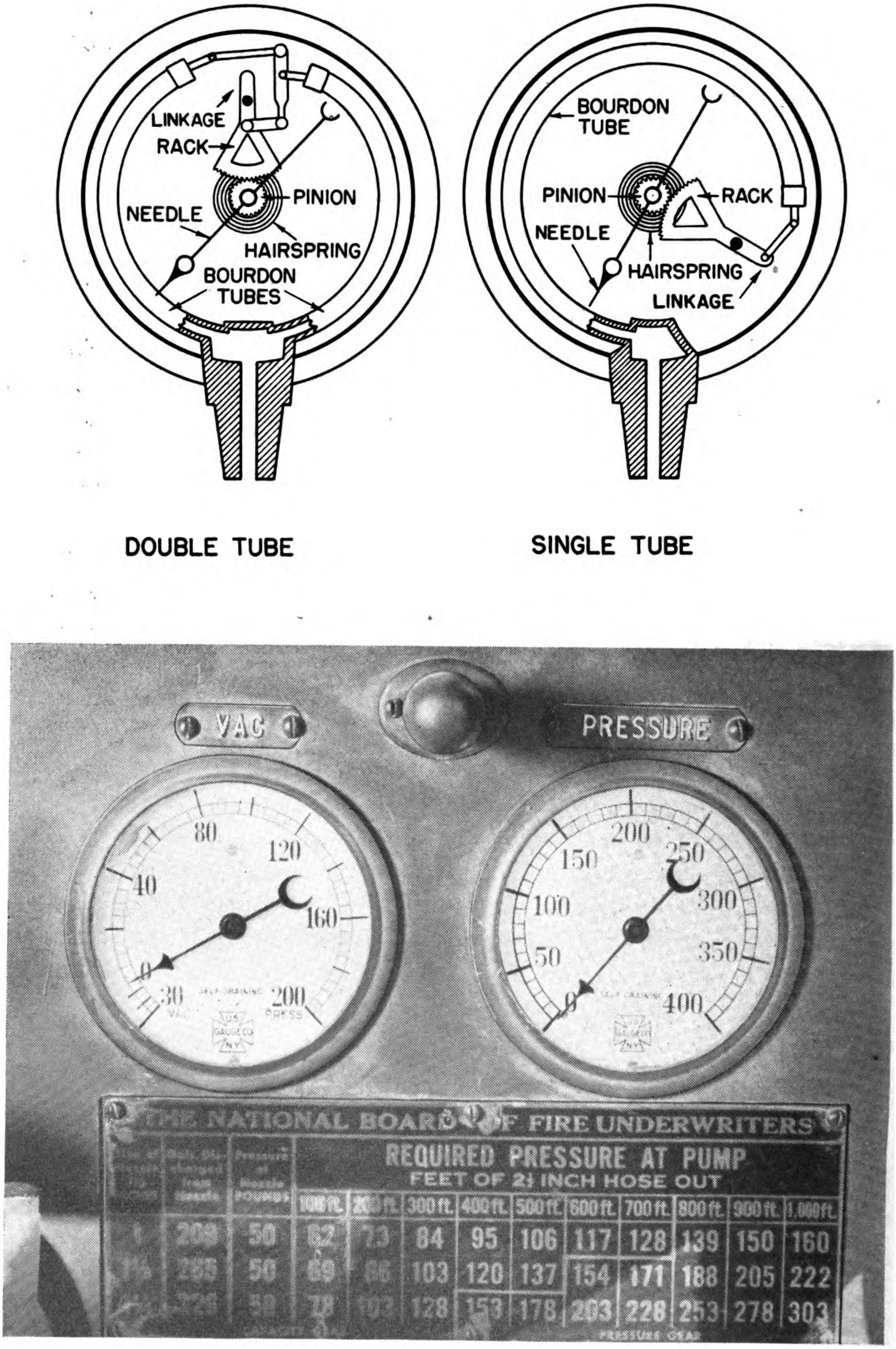


Figure 16. Bourdon gauges.

ence between the discharge and suction gauges is noted. The effective pressure, however, is that shown by the discharge gauge.

f. High-pressure gauges are equipped with suppressors to dampen the needle action. Such devices should not be tampered with in the field.

16. ENGINE COOLING SYSTEM (fig. 17). On most fire pumpers, the normal radiator capacity for cooling engines is insufficient to maintain proper operating temperatures when the vehicle is stationary and the motor is operating under pumping load. Heat exchangers are usually provided to augment the radiator cooling system and to maintain the necessary operating temperatures. The heat exchanger is a simple arrangement of coils within a water jacket. Water from the normal cooling system is diverted through the series of coils or cores and a controlled flow of cool water from the pump is bypassed through the water jacket around them. Heat is transferred from the radiator-cooling water to the pump-cooling water, the former being returned to the normal cooling system and the latter to the suction side of the pump. The temperature of the engine is maintained by regulating the flow of auxiliary cooling water through the heat exchanger. Provision may also be made for introducing water from the pump directly to the engine cooling system, but because of the pressure of the water from the pump and the possibility of introducing foreign matter into the engine cooling system this practice is recommended only for emergency use and with great care. (See fig. 17.)

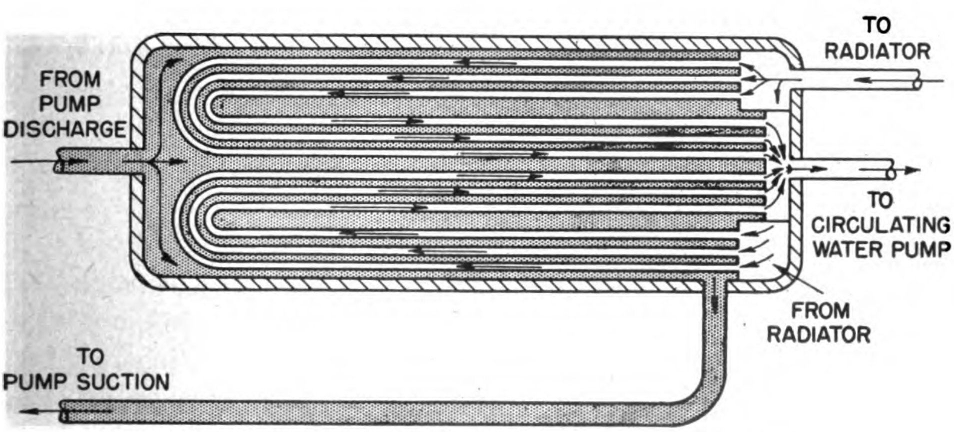


Figure 17. Heat exchanger and engine intercooler.

17. POWER TRANSMISSIONS. a. General. (1) Power is supplied to the truck-mounted pumps from the truck engine. Front-mounted pumps are connected to the engine through a combination friction and positive-drive clutch. The friction clutch acts only to bring the pump up to engine speed; then the positive clutch, consisting of interlocking

steel jaws, is engaged to transmit power during pumping. This arrangement results in smooth starting and a positive drive under load.

(2) Midship-mounted pumps are powered through a transmission power take-off. A transfer case and a drive shaft connected by universal joints transmit the power from the truck transmission to the pump. The truck clutch is used when engaging and disengaging the pump drive.

b. Care of pump power transmissions. If the positive jaws clash while the motor is idling the condition should be reported, for this means that the primary clutch needs replacing. All mounting bolts and brackets must be inspected after each run. All types of industrial clutches require lubrication at all points after each run with the equipment. After each fire, the clutch should be engaged and disengaged to make sure that it is not slipping or dragging. This may be determined by rotating the driven end of the clutch on the pump side by hand and noting whether or not there is any drag against the driving plates. To determine whether the clutch is too loose, engage the clutch and attempt to turn the pump by hand. If it turns easily, the clutch is too loose.

c. Transmission power take-offs. The transmission take-off units must be checked after each fire to make certain that all bolts holding the unit to the transmission, all connections, and the universal joint flanges, are tight; and that the shift lever is in its proper position.

18. CARE OF BOOSTER TANKS, VALVES, AND PIPING. a. The pump, hose reels, and the tank all are connected by pipe lines in which are sufficient valves for control. Water is pumped into the booster tank for use in mixing foam or for storage. Since water may remain for some time in the tank, any sediment in it settles to the bottom. Therefore, only clean water should enter the booster tank for it supplies water directly to the booster pump. In filling the tank from draft, the strainer must be fitted with a screen of not over 1/4-inch mesh, supported to prevent it from being submerged in sand.

b. The tank must be kept free of sand, for sand will move to the outlet screen and clog it. Also the tank must be checked periodically for leaks or loosening of rivets and baffle plates. Inspect the hold-down bracket on the tank for looseness, and pipe lines and fittings for leaks. Valve-stem packing nuts are repacked and adjusted when necessary. The cap at the filler opening is removed and the interior of the tank inspected regularly; if scale or rust is present, this fact is reported at the time the inspection is made. The outlet screen from the tank is removed and the interior of the tank thoroughly flushed out at a hydrant at regular intervals. The valves on the discharge manifold for the priming of centrifugal pumps must be absolutely air tight. To keep these valves working smoothly and also to insure their tightness they are treated with a waterproof grease each time after they are used.

Quick-acting or three-way valves may be kept in good working condition by similar treatment. A small paint brush is used to apply the lubricant to the valve disk or core. The valve is turned so that the lubricant will be carried into the valve body.

19. PUMPING FROM DRAFT. a. Location. As a site for the pump, select a point as close to the source as possible, one which has a solid foundation and is capable of bearing the weight of the truck and withstanding the vibration of the engine and pump. Pump lift should not exceed 12 feet. Shorter lifts are better. Set the emergency brake of the pumper, place the gear-shift lever in neutral position and open the throttle slightly to maintain good idling speed. Place chock blocks if the vehicle is on an incline.

b. Suction connections. (1) Check the gaskets of the suction line. All suction connections must be made tight with a wrench to prevent air leaks. Attach the suction strainer to the end of the suction hose. Attach a rope to the suction strainer to facilitate handling and tie it into position. Submerge the strainer 12 to 18 inches depending upon the capacity of the pump. Where the depth of water permits, the strainer should be at least 12 inches above the bottom.

(2) If the water is too shallow to suspend the suction line and strainer, the strainer must be protected to prevent sand and debris from being sucked into the pump. Boards, sheet metal, fruit boxes, the blade of a shovel, or any other object may be placed underneath and around the suction trainer to keep it clear. Tie the strainer into position with a rope to prevent it from drawing air. If it is impractical to use rope, place a large board or other heavy material over the suction strainer to keep it submerged. Close all openings, including drains and booster connections, on the suction side of the pump.

(3) Attach necessary hose lay-out to discharge outlets.

c. Pump priming. (1) DISPLACEMENT PUMPS. *(a)* Open discharge gates on hose line lay-out.

(b) Close churn valve.

(c) Place pump shift or transmission gear shift in pumping position. At the same time, increase speed of motor by opening throttle on quadrant to *moderate* motor speed.

(d) When pump is filled with water as indicated by pressure gauge, advance throttle slowly until required pressure is obtained.

(2) CENTRIFUGAL PUMPS. *(a)* Close discharge valve.

(b) Engage centrifugal pump and open valve in vacuum line, open valve between vacuum primer and pump casing, and increase engine speed *very slightly*.

(c) Open discharge valve slowly and maintain desired pressure as indicated by pressure gauge by advancing throttle slowly.

d. Pump operation. When operating a displacement pump which has a relief valve, set the regulating device at the desired operating pressure. Open or "crack" the cooling water-supply control valve to maintain an even motor temperature, as indicated by the motor meter. The efficient operating range indicated by manufacturer's recommendations, generally from 160° to 180° F., is used as a guide. The cooling water-control valve is manipulated as often as necessary to maintain the desired motor temperature, but the valve is never suddenly opend or closed. This practice heats or chills the motor too rapidly. Furthermore, the excess pressure coming from the fire pump is likely to damage the radiator or cooling system if the motor valve is opened too far.

e. Temporary shut-downs. When operating lines are shut down temporarily, open the churn valve (if the pump has one) enough to maintain the required suction on the pump. The throttle is retarded to keep the engine from racing, particularly in centrifugal pumps. As the operating lines are opened, it will probably be necessary to advance the throttle again to the desired pressure and simultaneously to close the churn valve slowly.

f. Shut-downs. When the signal is received to shut down, retard the throttle, open the churn valve, close the discharge valve, disengage the pump gears, close the auxiliary cooling line, bleed the hose lines and pump, and disengage the suction and operating lines.

g. Pumping from hydrants. The same general rules apply to pumping from a hydrant as to pumping from suction, with the exception that the rope and suction strainer are not needed.

(1) Spot apparatus near hydrant.

(2) Check hose gasket.

(3) Connect suction hose from pump to hydrant. Make connections "wrench tight."

(4) Close discharge valves and gates and churn valve.

(5) Open hydrant fully.

(6) Engage pump gear in proper operating position and advance throttle to desired pressure.

(7) When the signal for water is received, open discharge gates slowly and, if necessary, advance throttle to maintain desired pressure.

(8) When pumping from a substandard water system, pumps of large capacity often "pull vacuum" on the water system if the flow in the system is less than the discharge capacity of the pump. In this event, operators must watch the vacuum or compound gauge as well as the pressure gauge, and, regardless of the pressure maintained, should so regulate the throttle that the compound gauge does not show a vacuum. This is to avoid damage to the water system. Where flowing pressure is available in the water system, a minimum pressure of 5 pounds on the compound gauge is the best for preventing a vacuum.

If hydrants are of limited capacity, small tips are advisable for multiple hose lines.

(9) The same precautions for setting relief valves, governors, auxiliary cooling systems, churn valves and gauges when pumping from draft also apply to pumping from hydrants. Temporary shut-downs and final shut-downs while pumping from hydrants are handled in the same way as when pumping from draft.

h. Pumping from water tank. Water is pumped from the booster tank on the fire truck or trailer in much the same manner as it is pumped from a hydrant. Since the water level in the tank is above the level of the pump opening, the valve in the connection between tank and pump will permit water to flow from tank to pump by gravity, eliminating the necessity for priming. Because of this connection, care must be exercised to have the valve in this line closed when pumping from a hydrant or other gravity source of supply under pressure, since the excess pressure on the suction side of pump will be introduced into the tank and will result in overflowing and possibly bursting the tank.

i. Operation of front-mounted pumps. The procedure followed in operating the front-mounted pump is slightly different from that explained above.

(1) Engage pump while motor is idling. (Never attempt to engage pump while throttle is advanced and motor running at high speed.)

(2) Engage pump shift lever a little more than one-half turn. The first quarter turn engages the small friction clutch which brings the pump to the speed of the driving mechanism. The last quarter turn engages the positive drive members. The drive jaws on the positive drive may come end-to-end instead of engaging. When this happens, disengage the clutch lever fully and bring it back in again, repeating until the clutch engages properly.

(3) Always operate the shift lever slowly to prevent excessive slipping of the friction clutch in picking up the load and to prevent clashing of the positive clutch.

(4) It is not possible to generalize operating procedure for all types of pumps, but the foregoing will serve as a guide for operating most of them. If repeated attempts fail to produce satisfactory results, the condition should be reported immediately to the platoon commander.

(5) For specific information on classes 125 and 135 fire trucks and class 1010 trailer, see paragraph 114.

20. REFERENCES. In addition to the references included in appendix I, reference should also be made to standard operating instructions, maintenance manuals and parts lists, copies of which are furnished with each truck or trailer.

SECTION II
FIRE EXTINGUISHERS

21. PRINCIPLES OF EXTINGUISHING FIRES. Combustion, or fire, may be defined as oxidation taking place at a rate rapid enough to produce light and heat. Combustible materials heated to their ignition temperature unite with the oxygen of the surrounding atmosphere and burn. Ignition temperature, an adequate supply of oxygen, and the presence of fuel are all necessary to the support of combustion. Fire is suppressed by decreasing the temperature below the ignition temperature, shutting off the supply of oxygen, removing the fuel, or by a combination of these means. First-aid fire extinguishers cool the burning material and curtail the oxygen supply.

22. CLASSIFICATION OF FIRES. Accepted standard practice separates fires into three general classes:

a. Class "A" fires are fires on which the cooling and quenching effect of quantities of water is of first importance. These fires are fueled by ordinary combustible material such as wood, textiles, or rubbish.

b. Class "B" fires are fires on which the blanketing or smothering effect of the extinguishing agent is of first importance. These fires are fueled by small quantities of rapid-burning material such as gasoline or oils in open vessels or on floors.

c. Class "C" fires are fires in electrical equipment, where the use of a nonconducting extinguishing medium is necessary.

23. EXTINGUISHING AGENTS. Water is one of the best fire-extinguishing agents. Because of its low cost, availability, and ease of handling, it is the most widely used agent in fire protection. Some agents for combating class "B" and class "C" fires are dissolved in water—others are used separately—in first-aid fire extinguishers. Most of these agents extinguish fires by excluding oxygen from the burning material. Extinguishing agents and first-aid fire extinguisher appliances fall into six general classes, as follows:

a. Plain water.

b. Antifreeze water solutions.

c. Chemical-reaction type (soda and acid).

d. Foam solutions.

e. Vaporizing liquid (carbon tetrachloride base).

f. Inert gas (carbon dioxide).

24. METHODS OF PROPULSION. The extinguishing agent must be expelled from its storage compartment in the extinguisher and propelled to the fire. Methods employed for accomplishing this are as follows:

a. Pressure generated by hand-operated pumps.

b. Internally generated pressure produced by a chemical reaction.

c. Stored pressure or confined air under pressure.

d. Inert gas under pressure.

25. FIRST-AID FIRE EXTINGUISHERS. a. Plain-water extinguishers. In this primary type of extinguisher, the cooling and quenching effects of water are depended upon entirely for fire control. The extinguisher consists of a reservoir of water and a hand-operated pump for expelling the water. The extinguishers are of two types: the pump-tank and the back-pack. The pump-tank extinguisher is made with a fixed pump, the unit being operated while resting on the floor or ground. (See fig. 18.) The back-pack extinguisher consists of a hand-

Figure 18. Four-gallon pump-tank fire extinguisher.

operated pump built into a tank carried on the operator's back. (See fig. 19.)

1. 2½-gallon pump tank. *2. 5-gallon back-pack.*
3. 5-gallon pump tank.

Figure 19. Hand-pump tank fire extinguishers.

Pump-tank extinguishers have capacities of 2½, 4, and 5 gallons, while back-pack extinguishers are issued in the 5-gallon size only. Discharge may be either continuous or intermittent. In continuous operation, the duration of discharge from the 2½-gallon extinguisher is about 1 minute and that of the larger sizes proportionately longer. The horizontal range of the stream of water is 30 to 40 feet. For safety and reliability of operation, plain-water extinguishers are not installed where they will be subjected to temperatures below 40° F. Periodic checking and maintenance are required to keep plain-water extinguishers in good operating condition. The following procedure is recommended:

(1) Operate pump to check proper functioning.
(2) Empty tank, removing any foreign material present.
(3) Refill with clean water.
(4) Tighten packing gland so that without binding, it holds leakage to minimum.

(5) If operation of pump is stiff, place few drops of oil on rod. Refer to direction plate on tank.
(6) Replace hose and nozzle assembly, if unserviceable.
(7) Record date of inspection or recharge on attached tag.

b. Antifreeze extinguishers. (1) Plain-water extinguishers may be converted to antifreeze by adding granulated or flaked calcium chloride. To determine what antifreeze solution is necessary to protect the extinguisher from freezing, obtain the lowest recorded temperature of the locality and refer to the following table, which gives the freezing points of solutions containing varying amounts of calcium chloride.

Freezing Temperature (° F.)	Pounds of Calcium Chloride per Gallon of Water	Specific Gravity	Degrees Baume
10	2.25	1.139	17.7
0	2.94	1.175	21.6
—10	3.69	1.205	24.7
—20	4.19	1.228	26.9
—30	4.56	1.246	30.2

(2) When only a small number of fire extinguishers are to be rendered nonfreeze, it is preferable to use standard package unit nonfreeze charges which may be obtained through regular supply channels for the particular size of extinguisher involved.
(3) The above table is also used to determine the strength of antifreeze solutions in extinguishers. In preparing antifreeze solutions for low temperatures, allowance must be made for the increase in volume as the calcium chloride goes into solution. Ten pounds of calcium chloride dissolved in 2 gallons of water produce 2½ gallons of solution, while the increase in volume for weaker solutions is proportionately less. For temperatures below freezing extinguishers are equipped with antifreeze recharges and antifreeze devices. Recharging and maintenance of antifreeze are the same as for plain-water extinguishers.
(4) A tag, sticker, or label is attached to each extinguisher to indicate its contents.
(5) Because of the cooling and quenching action of its water solution, the antifreeze extinguisher is best suited for use against class "A" fires.
(6) Because of the corrosive action of calcium chloride nonfreeze solution, it is desirable to coat the interior of fire extinguishers to be used for this purpose with a bitumastic paint before charging.

c. Soda-and-acid extinguishers (fig. 20). (1) This extinguisher is similar to the two preceding types in that water is the extinguishing

agent. The chemicals are solely for the purpose of producing pressure to expel the solution. The reservoir of the extinguisher contains a solution of sodium bicarbonate. Supported in the top of the reservoir is a glass bottle half filled with sulfuric acid. The absorption of moisture by the acid is retarded by a loose stopper in the mouth of the bottle. When brought together the two chemicals react to produce carbon dioxide gas, the pressure of which expels the water from the device. When the extinguisher is inverted, the loose stopper falls partially clear of the acid bottle allowing the contents to mix with the soda solution. The tapered stem of the stopper meters the flow of acid into the soda solution at a predetermined rate. This metering action prevents excessive initial pressure, but permits a flow rapid enough to insure neutralization of all the acid before the solution is expelled from the extinguisher.

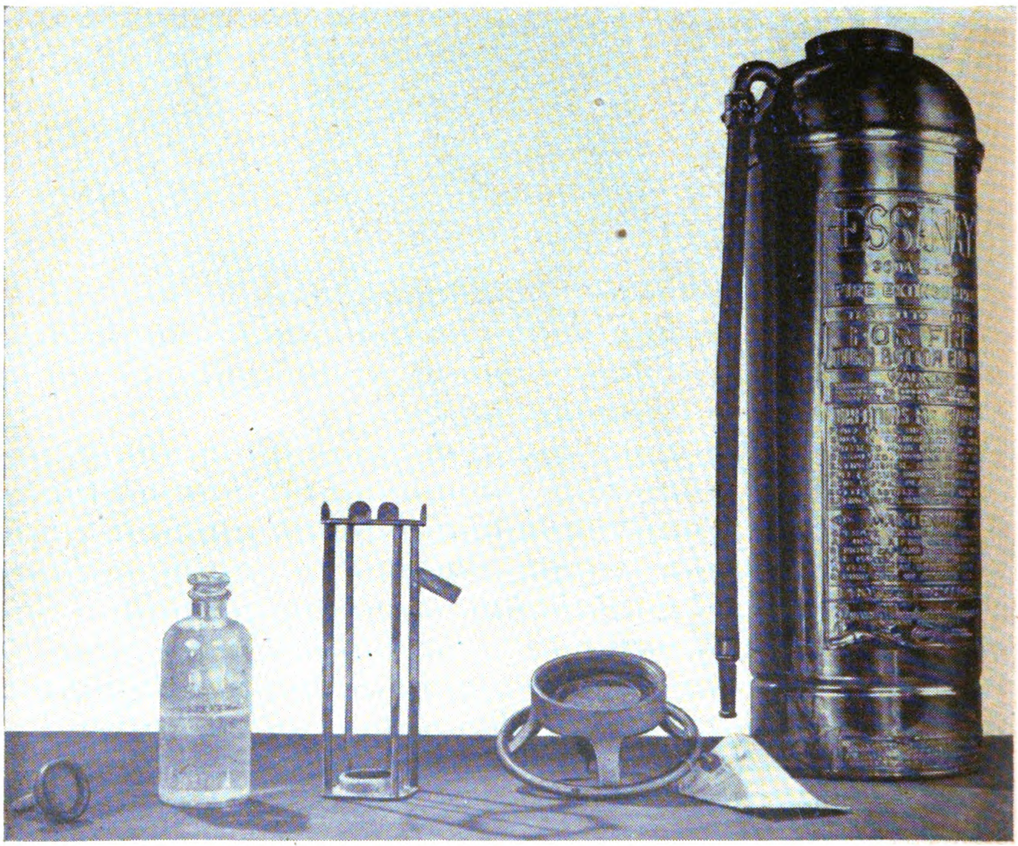


Figure 20. 2½-gallon soda-acid extinguisher.

(2) This extinguisher is provided in 2½- and 40-gallon sizes. The larger devices are mounted on wheels and are supplied in indoor and outdoor types which differ only in over-all width and length of handle. Operating characteristics, such as duration of discharge and stream range, of the 2½-gallon unit are comparable with the plain-water unit

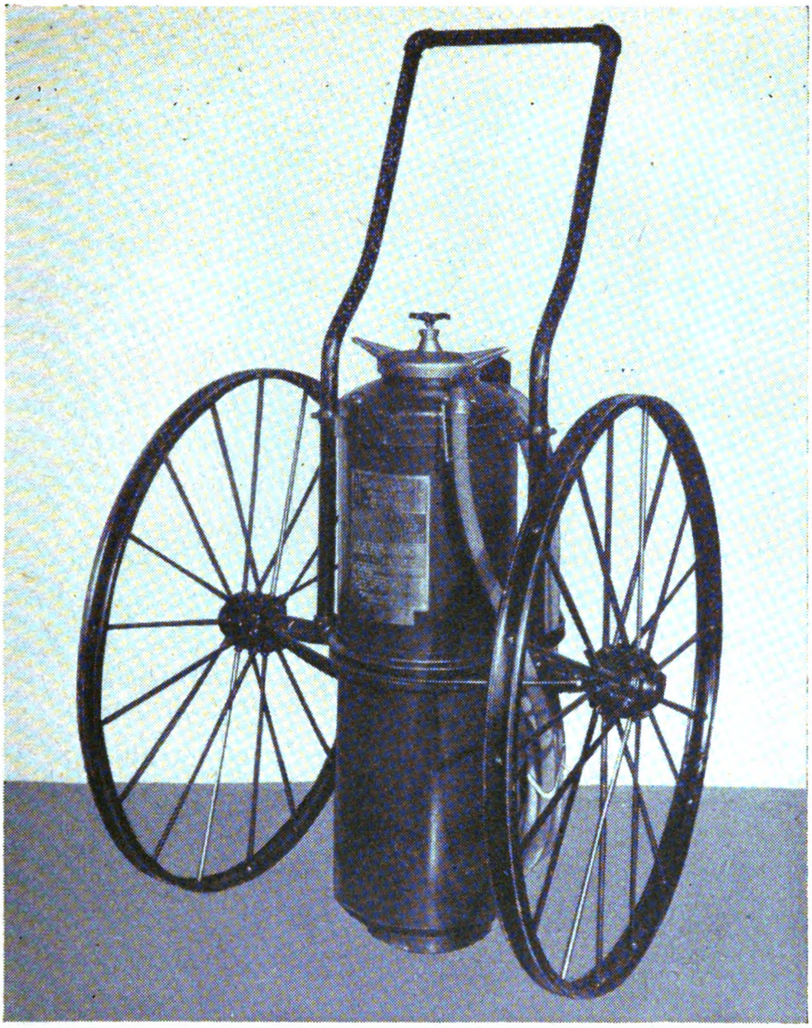


Figure 21. 40-gallon soda-acid outdoor chemical engine.

of the same size. The duration of the 40-gallon unit is approximately 15 minutes, with a range of 50 feet. (See fig. 21.)

(3) A water solution of sodium bicarbonate is not an antifreeze mixture and antifreeze salts must not be added to it. Such an addition precipitates out so much of the sodium bicarbonate that water cannot be expelled from the extinguisher. Furthermore, antifreeze salts create an excessively corrosive mixture which may weaken the walls of the extinguisher and render it unsafe to operate. At one point in the dilution of sulfuric acid by the absorption of water the freezing point of the mixture is above that of water. Hence, soda-and-acid extinguishers must not be subjected to temperatures below 40° F.

(4) After each use the extinguishers are cleaned and recharged. For recharging, a 2½-gallon extinguisher requires 4 fluid ounces of concentrated sulfuric acid, 1½ pounds of sodium bicarbonate, and 2½ gallons of water. The 40-gallon extinguisher is filled with propor-

tionately larger amounts of the same materials. The soda is completely dissolved in the water in a separate container and is then poured into extinguisher to prevent possible injury to its corrosion-resistant lining by stirring devices. The acid is poured into the bottle up to the filling mark, the stopper is replaced in the bottle and the bottle unit in its holder, the hose and nozzle are examined for possible obstructions, and finally the cap is replaced tightly. The date of recharging is recorded on the attached tag. Unless large numbers of extinguishers are to be changed at one time, the single unit charges furnished by the manufacturer are used.

(5) Effective maintenance requires that extinguishers be discharged and recharged annually. Educational value may be derived from the annual inspection by discharging the extinguishers before the assembled occupants of the building.

(6) After discharging the extinguishers, observe the following procedure:

(a) Wash out interior of extinguisher and acid bottle, permitting water to drain through discharge hose assembly.

(b) Replace gasket and hose assembly if unserviceable.

(c) Recharge according to directions.

(d) Record date of inspection and recharge on attached tag.

(e) If extinguisher shell has been damaged mechanically, take it out of service and replace it with another.

(7) Since soda-acid extinguishers are no more effective than plain-water pump type extinguishers and they have the disadvantage of requiring special recharges, they are not recommended for use in theaters of operations.

d. Foam extinguishers. (1) CHEMICAL REACTION TYPE. *(a)* Although from the outside, these extinguishers look like the soda-and-acid types, they differ in internal construction and extinguishing agent. The outer chamber contains a water solution of sodium bicarbonate; the inner chamber contains a solution of magnesium sulphate. (See fig. 22.) Added to the soda solution are ingredients which assist in forming and stabilizing the foam. The device is put in operation when it is inverted. This permits the contents of the two chambers to mix together, producing carbon dioxide. This gas permeates the liquid to form a tough durable foam which is expelled by the gas pressure. Discharge is continuous until the contents are exhausted.

(b) Foam extinguishers are issued in 2½- and 40-gallon sizes, the latter mounted on wheels and supplied in outdoor and indoor types. The 2½-gallon size produces 18 to 24 gallons of foam and the 40-gallon size, 300 gallons. Duration and range of discharge are about the same as for soda and acid and water extinguishers of the same size.

(c) The foam extinguisher is sensitive to low temperatures for the same reasons as is the soda and acid extinguisher. It cannot be treated

Figure 22. 2½-gallon reaction type foam extinguisher.

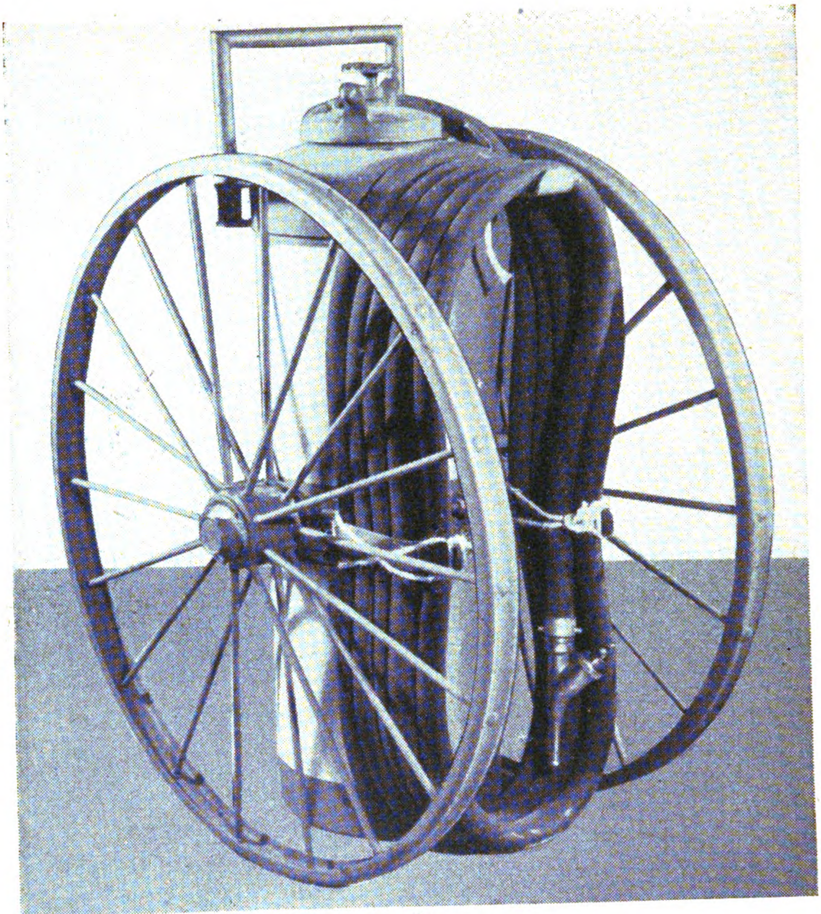
effectively with antifreeze and therefore is not installed where the temperature will fall below 40° F.

(d) In recharging the foam device, thoroughly clean the inside of the container and then add the two chemicals supplied in the recharge package. The aluminum sulphate (part A) for the inner chamber is dissolved in hot water. The sodium bicarbonate (part B) for the outer chamber is dissolved in lukewarm water, since hot water causes a detrimental chemical change. Refer to the direction plate on the extinguisher and instructions on the recharge package. The chemicals are dissolved in containers other than the extinguisher to protect it from mechanical injury. Pour the solutions into the proper parts of the extinguisher, replace the stopper on the inner chamber, and restore and tighten the screw cap. Finally, record the date on the attached tag.

(e) Maintenance is similar to that given for the soda-and-acid extinguisher.

(f) Foam extinguishers are suited primarily to class "B" fires because of the smothering action of the foam blanket laid down. For burning liquids in containers, an effective foam blanket is created by directing the stream against the inside wall of the vat or container just above the burning surface. Directing the foam stream into the burning liquid is not effective. To control burning liquid on a floor, the foam is applied so as to obtain complete coverage.

(g) Because of the cooling and quenching effect of the water in the foam, these extinguishers also are suited to class "A" fires although the value is less than that of the soda-and-acid, antifreeze, or plain-water



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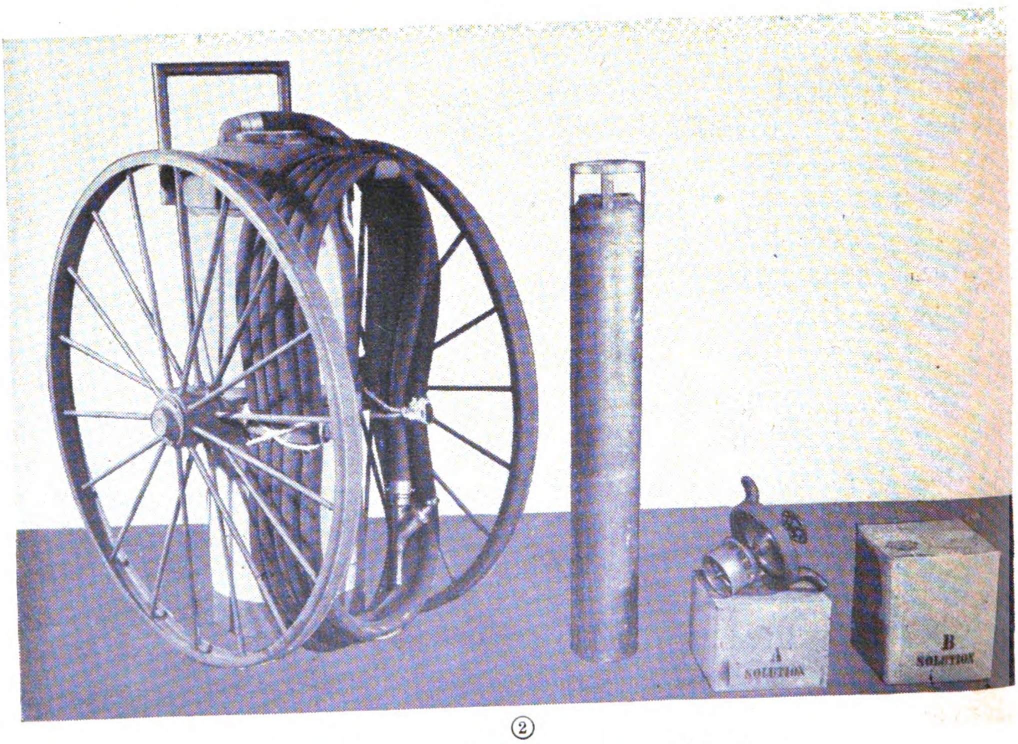


②

Figure 23. 40-gallon foam chemical engine.

types. Foam tends to adhere to the first object it strikes, thus building up a barrier which prevents penetration and saturation of piled combustible material.

(2) HAND-PUMP TYPE (fig. 24). Fire extinguishers of the mechanical foam-solution type also are available by a minor adaptation of the standard 4-gallon, water-pump type extinguisher. In this adaptation a special foam-producing nozzle is substituted for the standard nozzle and a unit charge of a special concentrated foam solution is added to the water content of the extinguisher and thoroughly mixed. Discharge of this solution through the special nozzle by the hand pump results in introducing air into the stream near the orifice, and subsequent agitation in the nozzle extension creates a frothy foam of suitable consistency. The application of this type foam extinguisher is identical with that of the chemical-reaction foam type.

e. Vaporizing-liquid extinguishers (fig. 25). (1) Extinguishers of this type use a specially prepared vaporizing liquid. This consists of purified carbon tetrachloride, with additional components to depress the freezing point to about —50° F. This liquid is a nonconductor of electricity. The liquid is propelled from the extinguisher by an

Figure 24. 4-gallon, pump type foam extinguisher.

hydraulic hand pump, an air-pressure hand pump, or stored air pressure within the appliance.

(2) The hydraulic hand pump is a double-discharge device built into the extinguisher. Liquid is drawn from the reservoir surrounding the pump and expelled through a fixed nozzle.

(3) The air-pressure hand pump is a single-action air pump also built into the extinguisher. Pressure is exerted on the contained liquid, which is forced out through a fixed nozzle.

(4) The stored air pressure device consists of two reservoirs, one holding air under pressure, the other holding the extinguishing agents. By turning the handwheel, the stored air pressure is released to the liquid chamber, forcing the liquid out through the hose and nozzle.

(5) Vaporizing-liquid extinguishers create a smothering effect, since the liquid immediately is transformed into a heavy vapor upon contact with fire or heated surfaces. This heavy vapor dilutes or excludes oxygen sufficiently to extinguish the fire. In using extinguishers of this type, especially in unventilated places, operators and other personnel should avoid breathing the liberated vapors or gases.

(6) Because of the smothering effect of the liquid and its inability to conduct electricity, this extinguisher is best suited for class "B" and class "C" fires. Since the cooling and quenching effect of the liquid is only one-tenth that of water, this extinguisher is not effective in controlling class "A" fires having deep-seated embers. In combatting burning liquids in containers, direct the stream against the inside wall above the burning surface. Splashing back over the burning surface, the liquid vaporizes quickly. Directing the stream into the blazing liquid is ineffective. To control burning liquid on a floor, direct the liquid at the base of the flame.

(7) These extinguishers are supplied in the following types:

(a) 1-quart extinguisher with either hydraulic or air-pressure pump.

(b) 1-gallon stored air pressure type.

(c) 3½-gallon, stored air pressure type, mounted on wheels.

(8) Duration of the hand-pump types is dependent upon the operator.

(9) All types discharge at the rate of 1 quart in 40 or 50 seconds. However, all vaporizing-liquid type extinguishers may be shut off at any time. The horizontal range of discharge is at least 20 feet.

(10) Extinguishers are recharged immediately after use, as follows:

(a) Hand-pump types. Replenish with extinguisher fluid specified by manufacturers. Record charging date on attached tag.

(b) Stored air pressure types. Refill to level indicated with liquid specified by manufacturers. Reestablish an air pressure of 100 pounds per square inch by operating built-in pump or by attaching an air line to fitting on extinguisher. Refer to instruction plate on extinguisher. Record charging date on attached tag.

1. Carbon tetrachloride refill.
2. 1-quart extinguisher.
3. 1-gallon extinguisher.
4. 3½-gallon extinguisher.

Figure 25. Vaporizing liquid extinguisher.

(11) Routine annual inspection is performed as follows:

(a) Hand-pump types. Discharge a portion of liquid into clean, moisture-free nonmetallic receptacle to check proper functioning of device. If liquid is clean and uncontaminated, pour back into extinguisher. Use liquid specified by manufacturer. Refer to instruction plate on extinguisher. Record date of inspection on attached tag.

(b) Stored air pressure types. Inspect to determine whether liquid chamber is filled to indicated level and air pressure is 100 pounds per square inch. If necessary, replenish with specified liquid and reestablish air pressure. Record date of inspection on attached tag.

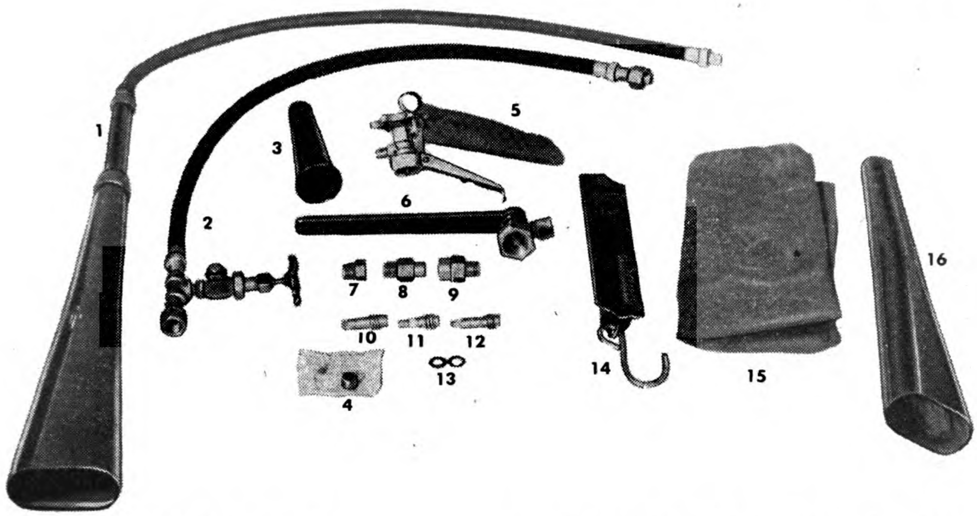
f. Carbon dioxide extinguishers (fig. 26①). (1) Extinguishers of this type consist of a container of liquefied carbon dioxide (CO_2) fitted with a special quick-opening valve which permits the release of carbon dioxide through a hand hose and specially designed nozzle. When liquefied carbon dioxide is released to atmospheric pressure it expands many times and appears as a "snow." Regardless of the temperature of the liquefied gas in the container, the temperature of the "snow" produced is —110° F.

(2) The smothering action of carbon dioxide makes it effective in controlling class "B" and class "C" fires. Since it is a nonconductor of electricity, carbon dioxide is especially effective against class "C" fires. Despite its low temperature, "snow" has only one-tenth the cooling effect of water, and, accordingly, is not effective in controlling class "A" fires.

1. 15-pound extinguisher. 2. 50-pound carbon dioxide cylinder. 3. 50-pound extinguisher.

① *Carbon dioxide extinguishers.*

Figure 26.



1. *Horn and hose assembly.*
2. *Bypass filling valve assembly.*
3. *Horn for 2-pound extinguisher.*
4. *Valve-sealing disk bushing.*
5. *Valve and cutter head.*
6. *Filling bonnet assembly.*
7. *Adapter for 2-pound extinguisher.*
8. *Adapter for 2- to 15-pound extinguisher.*
9. *Adapter for 20-pound extinguisher.*
10. *C–O Two Co. valve stem.*
11. *Walter Kidde valve stem.*
12. *American LaFrance valve stem.*
13. *Pressure relief disks and washers.*
14. *Spring balance.*
15. *Burlap bag.*

② *Components of carbon dioxide recharging and repair kit.*

Figure 26—Continued.

(3) With this extinguisher, the discharge is directed at the base of the flames. The discharge is applied to the burned surface even after the flames are extinguished. The "snow" thus deposited prevents flash-back from heated surfaces. On burning liquids the discharge is used to sweep the flame off the surface. Starting from the near side, move forward gradually with a slow movement from side to side.

(4) Since carbon dioxide is an inert gas, its use in any heavy concentration tends to exclude oxygen supply and may have an undesirable effect upon operators, especially since the gas has an exhilarating effect and tends to increase respiratory action. Although application from a hand fire extinguisher should not be dangerous to personnel except in closely confined spaces, it should be used carefully.

(5) These extinguishers are supplied in two sizes with rated capacities of 15 and 50 pounds of carbon dioxide. Duration of discharge is ½ minute for the smaller size and 1 minute for the larger. The horizontal range of discharge is about 8 feet.

(6) Recharging is done either by the nearest factory representative, or by using the manufacturer's transfer unit according to directions furnished with it. (See fig. 26②.) Maintenance requires weighing the

extinguisher carefully every 6 months to discover fluid loss. If the weight lost exceeds 10 percent of the charged weight stamped on the valve body, the extinguisher must be recharged. Record the date of inspection or recharging on the attached tag.
(7) In addition to hand fire extinguishers of the carbon dioxide type, personnel of troop fire-fighting organizations will frequently come in contact with fixed fire-extinguishing systems employing this gas. These systems are particularly to be found in boats, tanks, and airplanes. Their operation is similar in principle to that of the hand extinguisher, and specific information can be obtained by reference to applicable Army Air Forces and Ordnance publications. (See Technical Order 03–45C–1 and TM 9–1799.)

SECTION III
FIRE HOSE

26. GENERAL. Three general types of fire hose are used in the military service: cotton-jacket, rubber-lined; rubber-covered, rubber-lined; and rubber-covered, rubber-lined, reinforced suction. A fourth type hose which may be encountered, particularly in operations in foreign fields, consists of unlined linen or cotton hose.

a. Cotton-jacket, rubber-lined hose consists of a single or double woven cotton jacket lined with a rubber tube. Hose of this type is collapsible and must be used only under positive internal pressure conditions. Normally it is used for extending hose lines under pressure.

b. Rubber-covered, rubber-lined hose consists of a cotton canvas fabric covered on the outside and lined on the inside with rubber coating or a tube. Two types of rubber-covered, rubber-lined hose are in use with military fire equipment. Hose of this type, normally known as "booster line," is built to withstand moderately high pressures and is generally used for permanent hose lines connected to fire pumps taking water supply from booster tanks on fire trucks. The second type of this hose, known as "high pressure," is similar to the moderate pressure variety, but is built to withstand extreme high pressures and is normally used for permanent hose-line connections from high-pressure pumps on crash fire truck or trailers. Rubber-covered, rubber-lined hose may be collapsed under high vacuum or suction conditions, but will withstand moderate vacuum and frequently is used as a suction line when it is desired to draw small quantities of water from shallow streams or wells.

c. Rubber-covered, rubber-lined, reinforced suction hose is constructed similar to the ordinary rubber-covered, rubber-lined variety,

but has the benefit of a helical wire or metal winding set in rubber between reinforcing layers or wrappings to add the strength and rigidity necessary to withstand collapse under high vacuum. This type hose is used exclusively for suction-connection purposes.

d. Unlined linen or cotton hose is not a standard issue with the United States Army, but is used extensively by British and other European armies. It has no rubber inner lining and depends upon water swelling the special woven flax tube to render it watertight.

e. All the named standard types of fire hose, with the exception of the reinforced suction hose, are furnished in standard 50-foot lengths, each fitted with a male-threaded coupling at one end and a female-threaded coupling at the other. Hose lines of any desired length may be made by coupling lengths together. Suction hose is normally provided in standard 10-foot lengths, although longer or shorter lengths may be used. Suction hose is also fitted with male and female couplings. A special suction strainer or basket is furnished to thread onto the end of suction hose to prevent debris or other foreign matter from entering the pump. Rubber gaskets are fitted to each female coupling to provide a watertight connection when threaded to a male coupling.

f. Common sizes and types of fire hose, with their normal use, are shown in the following table:

Table of fire hose types, sizes, and standard use

Type	Diameter (Inches)	Length (Feet)	Use
Cotton-jacket, rubber-lined	1½	50	For laying 1½-inch hose lines.
Do	2½	50	For laying 2½-inch hose lines.
Do	2½ or larger	10 or more	Connecting pumps to hydrants or other source of water under adequate pressure.
Rubber-covered, rubber-lined booster lines	¾ or 1	50	Permanent attachment from pump on fire truck.
Rubber-covered, rubber-lined, high pressure	¾ or 1	50	Permanent connection from pump on crash fire trucks or trailers.
Rubber-covered, rubber-lined, reinforced suction hose.	2½ or 4	10	Suction connection for drafting water.

27. COUPLINGS (fig. 29). **a. Construction.** Fire hose couplings are generally of the expansion ring type, each pair of couplings consisting of three pieces. The male coupling is a single piece of brass, bronze,

aluminum, or malleable iron, with a male thread on one end and fastened to the hose by an internally expanded brass sleeve which holds the hose tightly against the inside of the coupling tailpiece. The female coupling is a similar tailpiece, with a female-threaded swivel of brass fastened to the tailpiece in a manner that leaves the swivel free to turn without turning the tailpiece. The female coupling also is attached to the hose by an expansion ring. A special expansion gasket is used between the hose and the male and female couplings when couplings are being expanded on hose, and must not be omitted. Both male and female couplings have projecting lugs to facilitate tightening joints. Special wrenches or spanners are provided to fit these lugs and are carried by all personnel.

b. Hose threads. Hose threads on fire hose supplied by the United States Army are of standard dimensions, known as American (National) Standard Fire Hose Coupling Threads, which are indicated below:

Table of American (National) Standard fire hose coupling threads

Nominal size (inches)	3/4	1	1 1/2	2 1/2	3	4 1/2
Diameter of male thread (inches)	1 1/16	1 3/8	1.99	3 1/16	3 5/8	5 3/4
Number of threads per inch	11 1/2	8	9	7 1/2	6	4

NOTE: Standard 1-inch thread is furnished on both 3/4- and 1-inch hose. Standard garden hose is furnished with 3/4-thread couplings.

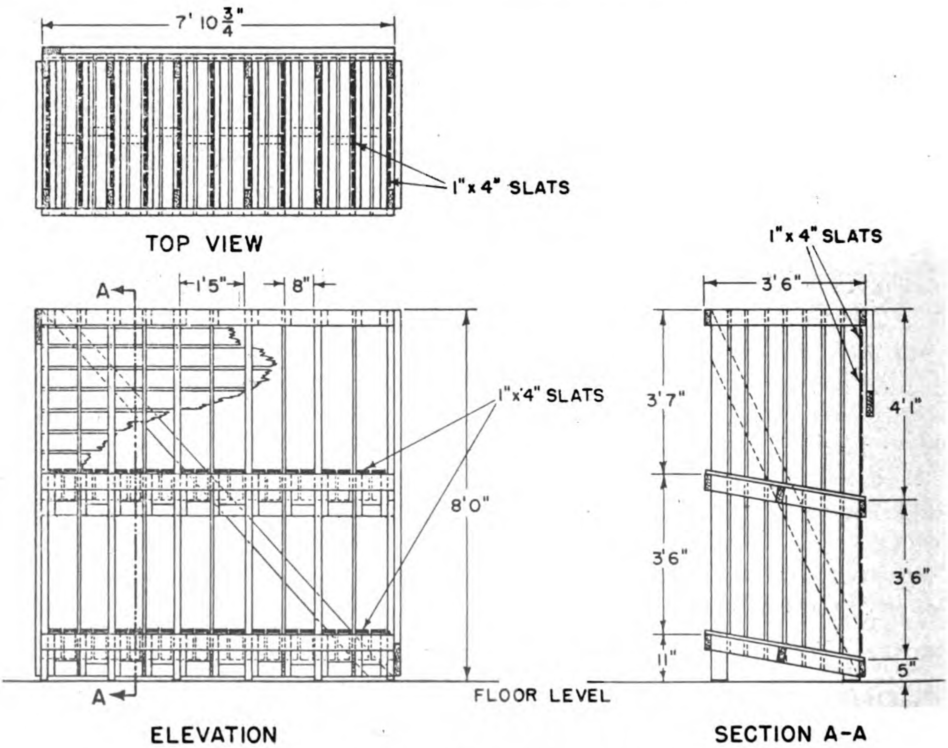


Figure 27. Hose storage bin.

c. Connection of United States Army equipment to foreign equipment may require special adapters, since threads and coupling types vary considerably over the world. Such adapters are best provided in the theater when the actual requirements are established. However, adapters to convert from standard fire hose to American and British standard pipe thread are normally provided.

28. CARE OF FIRE HOSE. Fire hose is subject to injury through lack of proper care. Replacement in forward areas is often difficult or even impossible, hence the following precautions must be observed:

a. Protection from mechanical injury. (1) Avoid dragging hose over ground or other rough surfaces.
(2) Avoid sharp folds which may result in permanent kinks. If folds in hose on trucks and on reels are changed frequently, strain at fold points is reduced.
(3) Guard against traffic damage. Vehicles should not be permitted to drive over hose lines. Hose bridges and special guards should be provided.
(4) Eliminate friction between hose and ground when working from a pumper. Special chafing blocks, shoes, or guards may be made for this purpose.
(5) Use special care when hoisting hose over sills, parapets, or other obstructions.
(6) Avoid closing shut-off nozzles rapidly, to prevent excessive back pressure.
(7) Do not drop or drag couplings on pavements.
(8) Handle frozen hose with great care.
(9) Only in extreme emergencies is serviceable fire hose used in flushing, drainage, or other nonfire purposes.
(10) Use oldest hose or salvage hose for drill work, except when hose lines are charged.
(11) Avoid operating pumps at pressures above those recommended for the hose.

b. Storage. Hose should be stored in a cool dry place. Storage for long periods near steam lines or radiators causes the rubber lining to become hard, brittle, and lifeless. Storage in a damp place results in mildew in the cotton fabric. Hose in storage is coiled loosely. Hose kept for any length of time should be removed frequently, washed out with water, and after thorough drying, returned to storage. (See figs. 27 and 28.)

c. Protection from moisture. (1) Dry all hose properly after use.
(2) Fold hose on trucks and reels to permit air circulation.
(3) Examine and reload hose periodically. Do not reload hose that is not thoroughly dry.

d. Effect of acids and solvents. (1) When water remains long in a hose, it reacts with the sulfur in the rubber to produce minute quantities of sulfuric acid which attacks the fabric cover. For this reason prevent water from dripping from one hose length to another.
(2) Gasoline, oils, and liquid solvents readily penetrate cotton-jacket hose and dissolve the rubber or cement which binds together the jacket and lining. Prevent contact of hose with these substances.

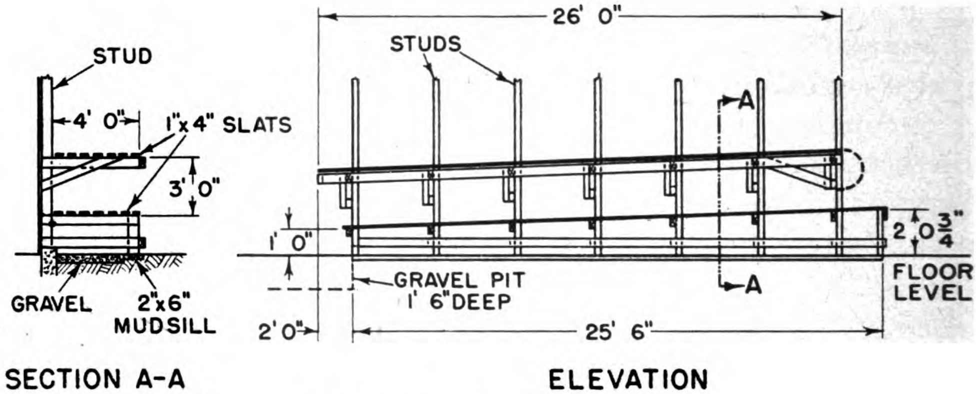


Figure 28. Hose drying rack.

e. Reloading hose. Hose in service on a fire truck is removed monthly and reloaded in a different position. Water is run through the hose at least once every 3 months; the hose is drained and dried thoroughly before reloading.

f. Drying hose. (1) Replace wet hose on fire apparatus with dry hose, if possible. Where supply is limited, dry a few lengths at a time to keep fire truck in service.
(2) Brush or wash all dirt from hose jacket. Oil may be removed by washing with soap or mild alkali followed by a thorough water rinse.
(3) Place hose in a tower or on a rack to dry. Avoid drying in direct rays of sun or on concrete or other open surfaces. Do not pile one length of hose on another, but arrange each length so that air circulates freely around it.

29. TESTING HOSE. a. Fire hose is tested semiannually, preferably spring and fall, to determine its serviceability. Service tests are made at 200 pounds pressure for double-jacket hose and at 150 pounds for single-jacket hose.

b. Tests may be made with pumping engines, if proper attention is paid to the relief valve and the pressure-regulator setting and if pressure is developed gradually. Centrifugal pumps are partially self-relieving and, by careful adjustment of the throttle setting, pressure may be controlled accurately.

c. When testing hose, approximately four lengths are tested in a single line at one time. Fill the line with water with the nozzle open, to evacuate all air. Gradually close the shut-off nozzle at the discharge end. Develop the pump pressure to the test figure and maintain it while the line is being examined for defects. Upon completion of the test reduce the pressure gradually.

d. Clean and dry serviceable hose carefully before returning it to service. Defective hose which cannot be coupled in shorter lengths is replaced at once.

e. Tests on hard and soft suction hose are made at the maximum static hydrant pressure encountered at the particular post. Hard suction hose is tested by vacuum.

30. GENERAL MAINTENANCE. a. Rubber-covered, rubber-lined hose. Maintenance described in paragraph 28 applies to cotton-jacket, rubber-lined fire hose, although statements on mechanical injury, storage and effect of acid and solvents apply to all types. Rubber-covered, rubber-lined hose is examined periodically for defects. Vehicles on which this hose is furnished are so used that pressure tests under maximum service conditions are constantly being made. Rubber-covered, rubber-lined hose need not be dried, since a certain amount of moisture is vital to the maintenance of rubber.

b. Suction hose. To obtain good results all parts of the suction hose must be kept in good repair.

(1) Gaskets must be unbroken and free from foreign materials.
(2) Threads on couplings must be clean and undamaged.
(3) Chafing shoes are used at all times.
(4) Pumps are not lubricated with excessive amounts of oil or grease.
(5) Exterior and interior of suction hose are thoroughly examined at frequent intervals.

c. Hose record. Each length of hose is stamped with an identifying number immediately upon delivery. A book record is kept of the date received, name of manufacturer, date of periodic testing, test pressure, and remarks concerning results of tests, repairs, unusual features, or causes of failure.

d. Replacing couplings. (1) Coupling threads are examined after each use and any damaged or defective couplings repaired. Dirty or stuck couplings are cleaned, freed, or lubricated by spinning in soapy water. Gasoline, oil, or grease are not used to clean or lubricate couplings because of their harmful effect on the hose. Flake graphite is used to lubricate all swivels. Gaskets are inspected frequently, and deteriorated or broken ones are replaced. Gaskets should not project into the waterway, particularly at the nozzle couplings; such a condition results in a ragged fire stream.

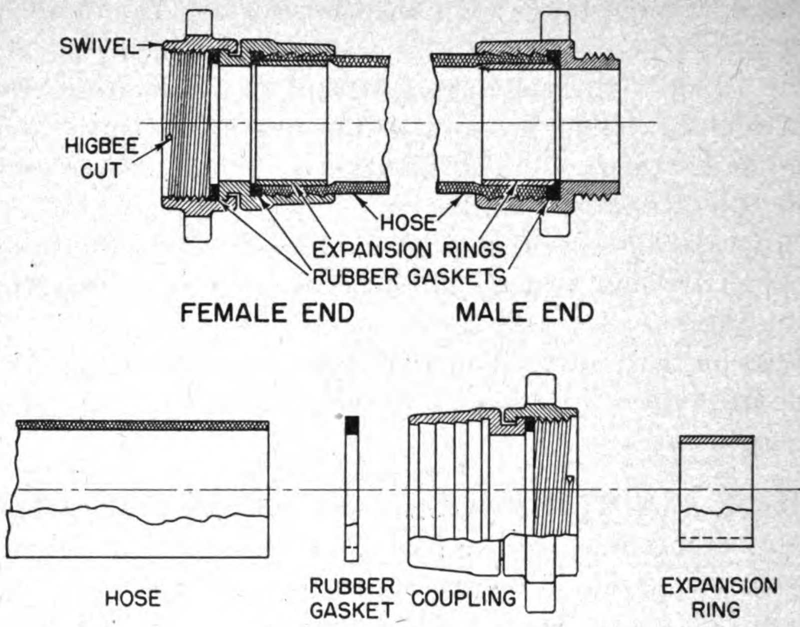


Figure 29. Standard fire-hose coupling.

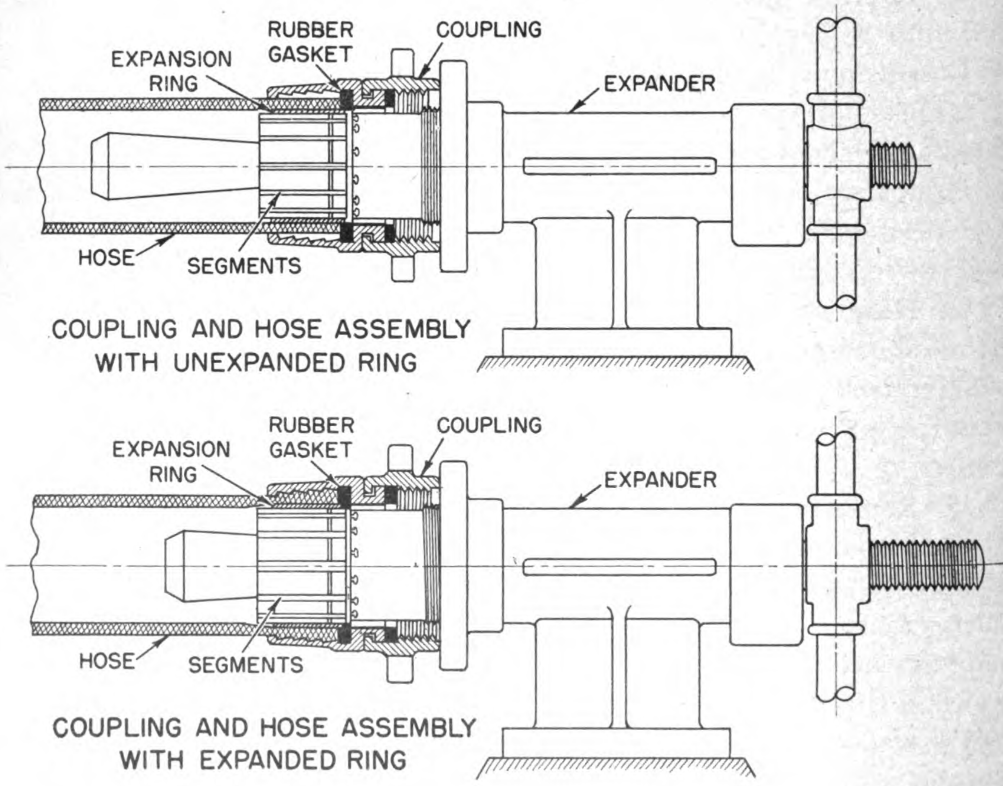


Figure 30. Fire-hose coupling expander.

(2) Special expanders for recoupling hose and expansion rings and gaskets are standard equipment with military fire-fighting organizations. In expanding couplings, ends of the hose are trimmed smooth and fitted into tailpieces of the couplings with expansion gaskets between. The expansion ring, which has a diameter slightly less than the inside diameter of the hose is then fitted from the open end of the coupling. The expansion ring must be fitted carefully. The expanding tool, which consists of a series of movable segments forming a cylindrical drum is then inserted behind the expansion ring. Turning the handle of the expanding tool forces these segments outward, increasing the diameter of the cylinder until the expansion ring has been stretched to make a tight fit against the hose in the tailpiece of the coupling.
(3) Every effort should be made to salvage good portions of defective hose lengths by removing the defective part and recoupling the hose in shorter sections. The minimum length of hose section to be salvaged in this manner is 25 feet, unless shorter lengths can be used for special purposes.

SECTION IV

PROTECTIVE CLOTHING AND EQUIPMENT

31. GAS MASKS. **a.** The standard Army gas mask, known as the "service mask," affords protection to the wearer from all normal concentrations of war gases likely to be encountered in field operations. It does not protect against carbon monoxide or ammonia, both of which are likely to be present in fire-fighting operations. It should not be worn for fire-fighting purposes. Standard Army all-purpose type cannisters are especially designed to protect against carbon monoxide and moderate concentrations of ammonia in addition to affording a degree of protection against normal war gases. The all-purpose type cannister may be used with the standard service type mask assembly, since the cannisters are interchangeable. Both types of mask should be maintained separately in readiness for instant service. Diaphragm type gas mask facepieces are generally preferred for fire-fighting purposes.

b. Gas masks cannot supply the oxygen necessary to sustain life in the wearer. They will filter out solid and liquid particles, neutralize toxic and irritating gases and vapors, and render the oxygen content of the air safe to breathe. Atmosphere containing at least 16 percent oxygen is necessary to sustain life. Gas masks should never be worn

in atmospheres where the oxygen content is likely to be less. All-purpose type cannisters supplied by the Army are designed to be used in atmospheres containing not more than 1 percent of toxic vapors under normal circumstances and not more than 2 percent by volume under extreme concentrations. Although longer protection could be afforded against other gases, a time limit of 2 hours use is imposed upon all-purpose cannisters because of the limited protection afforded against carbon monoxide. Each all-purpose cannister is labeled to provide space for registering each period of use. It is absolutely necessary to record each use immediately to insure safety to subsequent users of the cannister.

c. For complete nomenclature and technical details regarding service and all-purpose type gas masks see TM 3–205.

32. PROTECTIVE CLOTHING. a. Personal clothing. Personal clothing issued includes a special duck fire-fighting, turn-out coat, fire-

Figure 31. Asbestos suit.

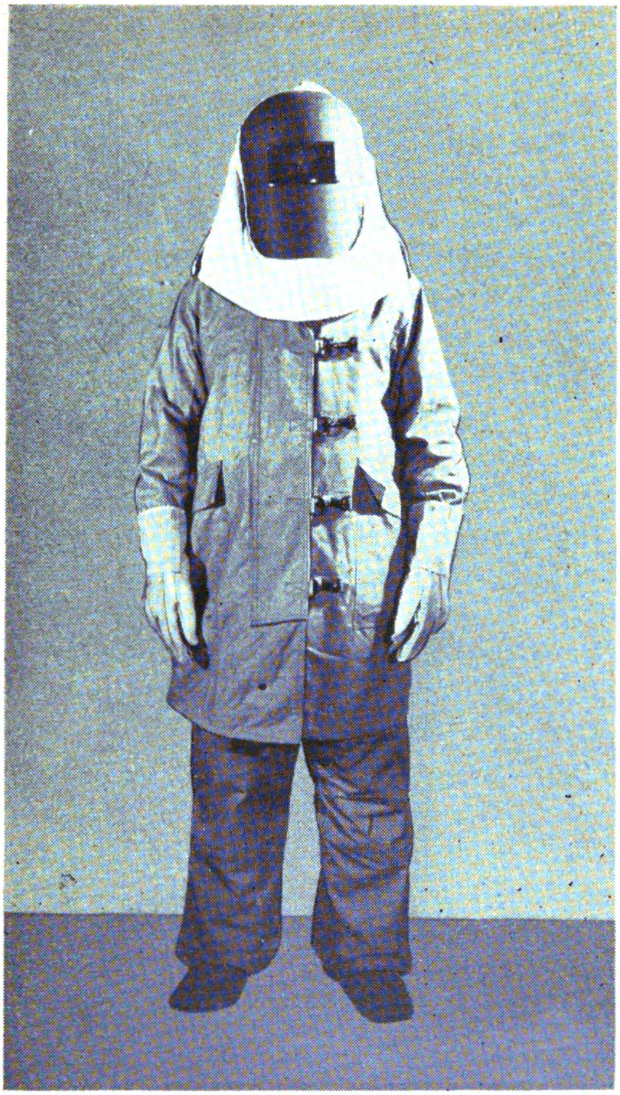


Figure 32. Protective face shield and heavy gloves.

men's bunking trousers, suspenders, gloves, and rubber boots. Special safety helmets are not issued. Regulation military helmets afford more protection, particularly under combat conditions. Fire-fighting clothing gives maximum protection to the wearer against water, cold, and physical injury without sacrificing bodily freedom. It can be put on quickly. Normally, the regulation helmet and turn-out coat are worn during response to fire and at subsequent fire operations. Boots and trousers are worn as occasion requires and time permits. All fire clothing is intended to be worn over the uniform. When not in use bunking trousers are arranged with legs fitted over boots, so that the wearer has only to step into his boots, pull up and fasten his trousers, and put on coat and helmet, which should be kept in the handiest place. Gloves are carried in turn-out coat pockets. (See figs. 48 to 52.)

b. Special clothing. (1) ASBESTOS SUIT. Special asbestos suits protect personnel particularly in airplane crash rescue work. A single-piece asbestos suit, complete with feet, trousers, coat, gloves and helmet, inner-lined for heat protection and designed for rapid donning, is preferable. Some asbestos suits consist of separate trousers (with feet), coats, gloves and hooded helmets, but such suits are not convenient for emergency use and do not give continuous protection to the entire body. Asbestos is a poor insulator and does not give protection against heat. Also, asbestos fabric is highly absorbent and quickly becomes saturated with water or flammable liquid. Exposure to extreme heat or direct flame in a saturated suit will result in steam scalding or suffocation of the wearer, or ignition of the inside garment. Heavy inner linings of wool have been added to one-piece asbestos suits to guard against this hazard. Prolonged exposure to extreme heat may be fatal, and extreme care must be exercised in the use of asbestos suits. Wearers should be subjected to a continuous drenching application of water, fog, or spray during exposure to fire. Helmets furnished with asbestos suits protect the face from direct flame, but do not protect against smoke, gases, or prolonged heat.

(2) PROTECTIVE FACE SHIELDS. Full asbestos suits are worn by personnel engaged in rescue work. Special protective face shields similar to a welder's helmet, fitted to a bakelite or plastic safety helmet and with asbestos hood for protection of back of head and neck, are provided for personnel directing high-pressure hose streams on airplane crash fires at close range.

(3) PROTECTIVE GLOVES. Heavy, reinforced leather gloves with protective gauntlets are provided for personnel operating high-pressure hose lines.

SECTION V

MISCELLANEOUS EQUIPMENT

33. FIRE-FIGHTING EQUIPMENT SETS. a. Set No. 1 (fig. 33). Fire-fighting equipment set No. 1 consists of a minor assortment of hand fire extinguishers and fire tools, including recharges and initial operating supplies. It is designed and issued for carrying on ¼-ton trucks assigned to fire-fighting organizations. Because of the limited size of the vehicle the fundamental purpose of this equipment is to provide readily available first-aid fire equipment only. (See app. II for list of equipment.)

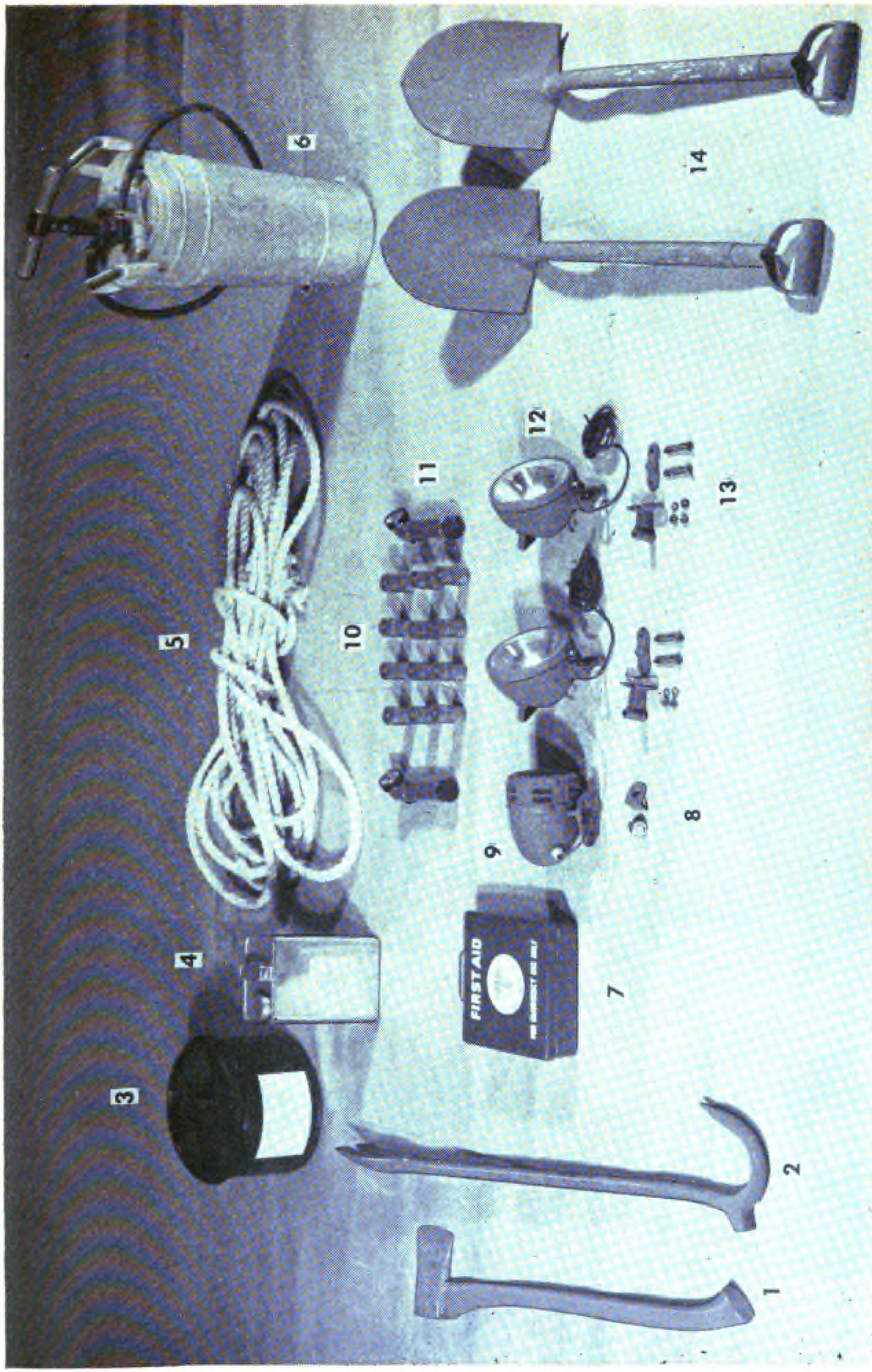


Figure 33. Fire-fighting set No. 1.

1. *Chopping ax.*
2. *Clawbar.*
3. *Nonfreeze unit recharge.*
4. *Carbon tetrachloride refill.*
5. *¾-inch rope.*
6. *4-gallon pump tank extinguisher.*
7. *First-aid kit.*
8. *Siren bracket.*
9. *Siren.*
10. *Flashlight batteries.*
11. *Flashlights.*
12. *Spotlights.*
13. *Spotlight brackets.*
14. *D-handle, round-point shovels.*

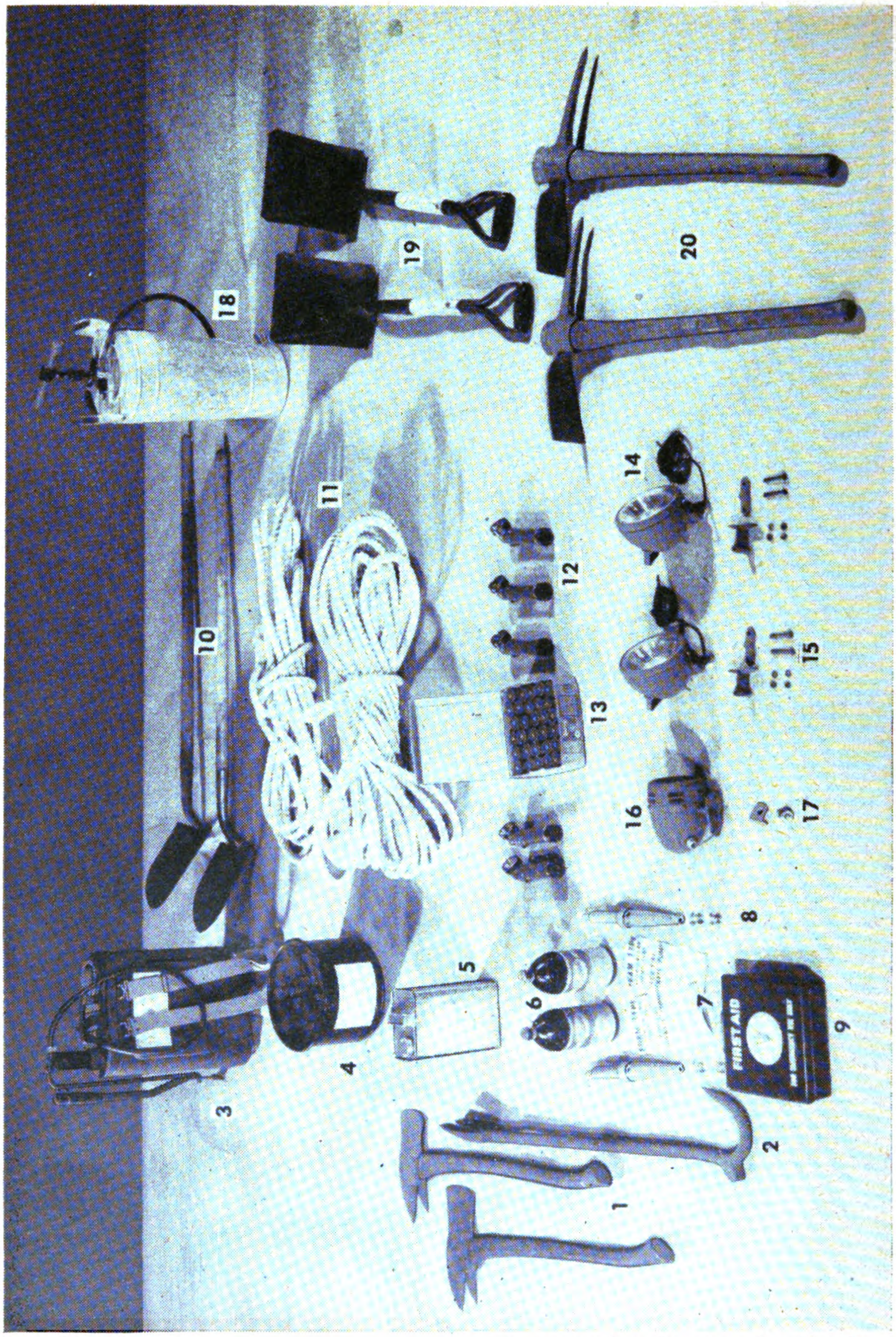


Figure 34. Fire-fighting set No. 2.

1. *Pickhead ax.*
2. *Clawbar.*
3. *5-gallon back-pack extinguisher.*
4. *5-gallon nonfreeze charge.*
5. *Carbon tetrachloride refill.*
6. *Foam charge for 4-gallon extinguisher.*
7. *Foam conversion labels.*
8. *Foam conversion nozzles.*
9. *First-aid kit.*
10. *Long-handle, round-point shovels.*
11. *1-inch and ¾-inch rope.*
12. *Flashlights.*
13. *Flashlight batteries.*
14. *Spotlights.*
15. *Spotlight brackets.*
16. *Siren.*
17. *Siren bracket.*
18. *4-gallon pump tank extinguisher.*
19. *D-handle, square-point shovels.*
20. *Pickmattocks.*

b. Set No. 2 (fig. 34). Fire-fighting equipment set No. 2 is similar to set No. 1, except it contains a larger assortment of equipment and is designed for use in connection with ¾- or 1½-ton towing vehicles for fire and crash trailer sections. (See app. II for list of equipment.)

34. EQUIPMENT FOR CLASS 325 CRASH FIRE TRUCK. Equipment furnished as standard on class 325 fire trucks is designed to afford fire-fighting organizations the greatest possible flexibility in meeting all probable conditions within the load-carrying capacity of truck without sacrifice of vital water-carrying capacity. In addition to basic equipment listed in paragraph 10, the miscellaneous appliances include items indicated in appendix II.

35. EQUIPMENT FOR CLASS 125 OR 135 CRASH FIRE TRUCK. In crash fire truck operations, utilization of maximum water-carrying capacity on the truck is paramount, and the miscellaneous items of fire equipment furnished are limited to the essential operating items. (See app. II.)

36. EQUIPMENT FOR CLASS 1000 FIRE TRAILER. Equipment furnished with the class 1000 fire trailer is in addition to that supplied with fire-fighting equipment set No. 2 and is sufficient to provide a complete fire-fighting unit with the combined trailer and towing vehicle equipment. Since they do not possess a self-contained water supply, trailer units are not intended for use where neither installed nor improvised water supply exists. Under some conditions auxiliary water tanks can be improvised and mounted on 1½-ton towing vehicles to provide a moderate water supply. Excess hose furnished with class 1000 trailers also may be loaded on towing vehicles for expediency. (See app. II for list of equipment.)

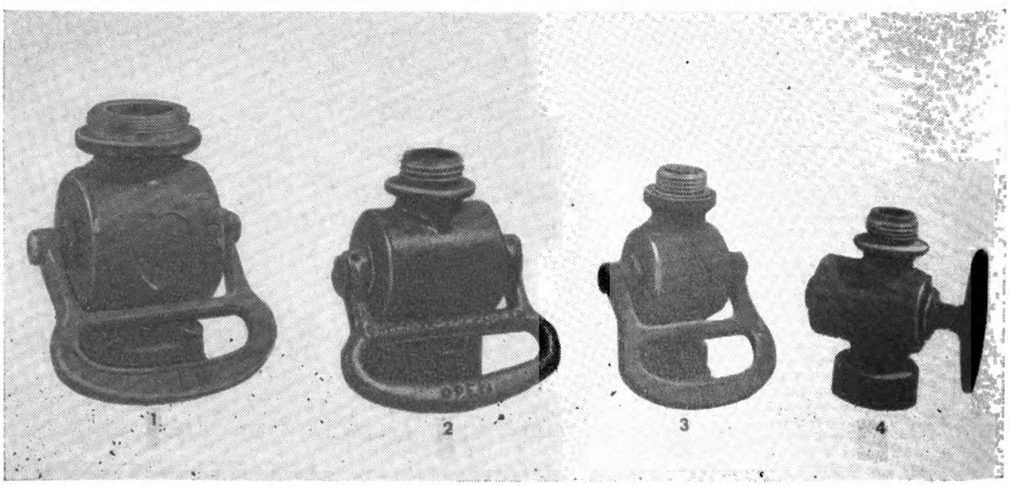
37. EQUIPMENT FOR CLASS 1010 OR 1020 CRASH TRAILER. Class 1010 or 1020 crash trailers have all equipment necessary for operation against moderate airplane crash fires, utilizing high-pressure water, fog, and foam fire-extinguishing mediums, and to effect rescues. (See app. II.)

38. NOZZLES. a. Shut-off nozzles. (1) TWO AND ONE-HALF INCH. Shut-off type fire nozzles for attachment to 2½-inch hose lines are furnished as standard equipment on class 325 fire trucks and class 1000 fire trailers. Nozzles are complete in three pieces, consisting of play pipe stub, shut-off valve (fig. 35), and tip, which are assembled by threading together. Play pipe has 2½-inch standard female hose thread for attachment to 2½-inch hose lines. The play pipe barrel is

tapered to remove turbulence from the water stream before passage through the shut-off valve, which is threaded to the upper end of the play pipe. Nozzle tips are threaded to the opposite end of the shut-off valve and are further tapered to straighten the stream after passing through the shut-off. The nozzle tip bore is machined to create a smooth stream at the orifice. Rubber gaskets are furnished in all female thread insets to provide watertight connections. Normally, 1-inch nozzle tips are provided as standard; these are most effective for general purposes, although tips ranging from 3/4- to 1 1/4-inch diameter bore are available for special purposes.

(2) ONE AND ONE-HALF INCH. This size shut-off nozzle is also furnished as standard equipment on class 325 fire trucks and class 1000 fire trailers. It is designed for direct attachment to 1 1/2-inch hose and is similar in construction to the larger 2 1/2-inch nozzle. A 1/2-inch tip is normally provided, but assorted tip sizes also are available. Tips are removable, with the tip thread designed to accommodate standard 3/4-inch, or 1-inch, chemical or booster line threads, or other appliances with the same thread. One and one-half inch hose lines and nozzles are usually used on long lines where the excessive friction loss reduces the available flow of water, or on short or inside lines where water supply is limited or it is desirable to reduce the water-discharge quantity to prevent excessive water damage.

(3) ONE INCH. One-inch shut-off nozzles are standard equipment with class 325 fire trucks. They are similar to 1 1/2-inch nozzles with the exception of tip sizes and hose connection thread. Threads are designed to fit standard 3/4-inch, or 1-inch, chemical or booster-line hose. Tip sizes range from 3/16- to 5/16-inch diameter. Tip threads permit attachment of regular 3/4-inch garden hose. One-inch booster-



1. 2 1/2-inch nozzle valve. *3. 1-inch nozzle valve.*
2. 1 1/2-inch nozzle valve. *4. 3/4-inch nozzle valve.*

Figure 35. Shut-off nozzle valves.

line nozzles are extensively used for first lines from self-contained booster tanks on trucks, and for extinguishing incipient fires. They also are of considerable value on moderately large fires where water supply is extremely limited.

(4) THREE-QUARTER INCH. This size garden hose nozzle is furnished for extending garden hose lines from booster or chemical hose lines, or for attachment to ordinary garden hose thread outlets. Garden hose is also useful in replenishing water supply in tanks.

b. Combination fog and straight-stream nozzles (fig. 36). Special nozzles for attachment to 1½-inch hose have double waterways, one of which produces a straight stream through a smooth bore tip and the other a fog mist through a specially designed spray nozzle tip. Flow of water through either waterway is controlled by a single three-position shut-off valve built into the nozzle. The spray nozzle tip is removable, and a long gooseneck pipe with special fog spray tip may be attached to the nozzle by a bayonet type socket in the nozzle when the spray tip is removed. Fog tips are effective in controlling spill fires of oils or other heavier petroleum products, and with practice can also be used with some effectiveness on smaller gasoline fires. They also are effective in providing a protective spray for personnel operating in close proximity to fire.

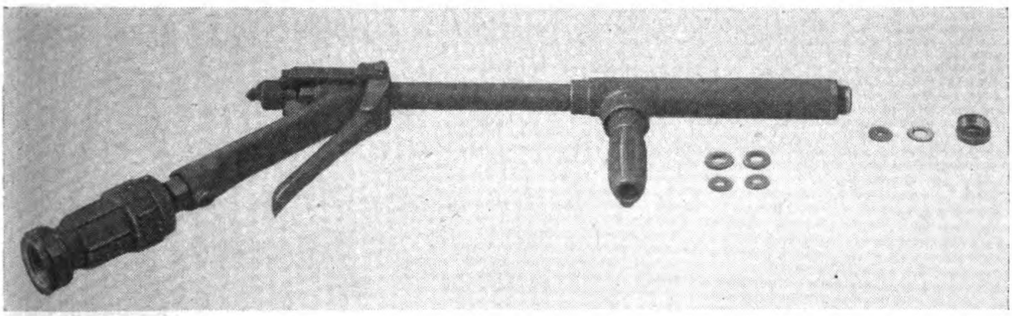


Figure 36. Combination fog and straight-stream nozzle with extension applicator.

c. High-pressure spray nozzle (fig. 37). The high-pressure spray nozzle is designed especially for and furnished with class 125 and 135 crash trucks and class 1010 and 1020 crash trailers. High-pressure nozzles furnished with crash truck and trailer are basically similar in design and operation, except that those furnished with trailers have about one-half the discharge capacity of those furnished with crash trucks. Nozzles fit directly on the threaded-end couplings of ¾- or 1-inch high-pressure hose. Removable disks in the nozzle tips control the discharge. A convenient handle knob permits controlling the character of the stream, which can be varied at will from a long-range, penetrating spray stream of high pressure to a wide, fan-shaped fog spray of limited carry.

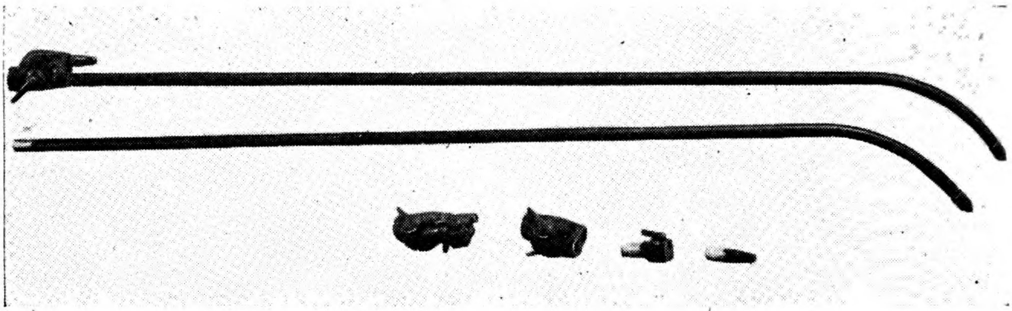


Figure 37. High-pressure spray nozzle.

d. Foam applicator nozzle with hip pack (fig. 38). A special foam-producing nozzle, complete with pick-up tube and sling-type carrier basket for liquid foam solution, is furnished with all crash and fire trucks and trailers. Nozzles are threaded to fit directly on ¾- or 1-inch high-pressure or booster hose lines and may also be attached to 1½-inch hose lines by removing the threaded tip from 1½-inch nozzles. Special foam-producing liquid in proper proportion is introduced into the water stream at the nozzle orifice by the injector action of the water passing through the orifice. The subsequent mixture of air through nozzle apertures, and agitation in the extended nozzle tube, produces a tenacious foam which is effective in blanketing burning liquids and in coating surfaces to be extinguished or protected. Foam blankets are highly effective in preventing flash-back fires from ignited flammable vapors. The flow of foam can be started or stopped at will by raising or lowering the pick-up tube in the foam liquid supply container. The supply of foam liquid can be replenished readily with but

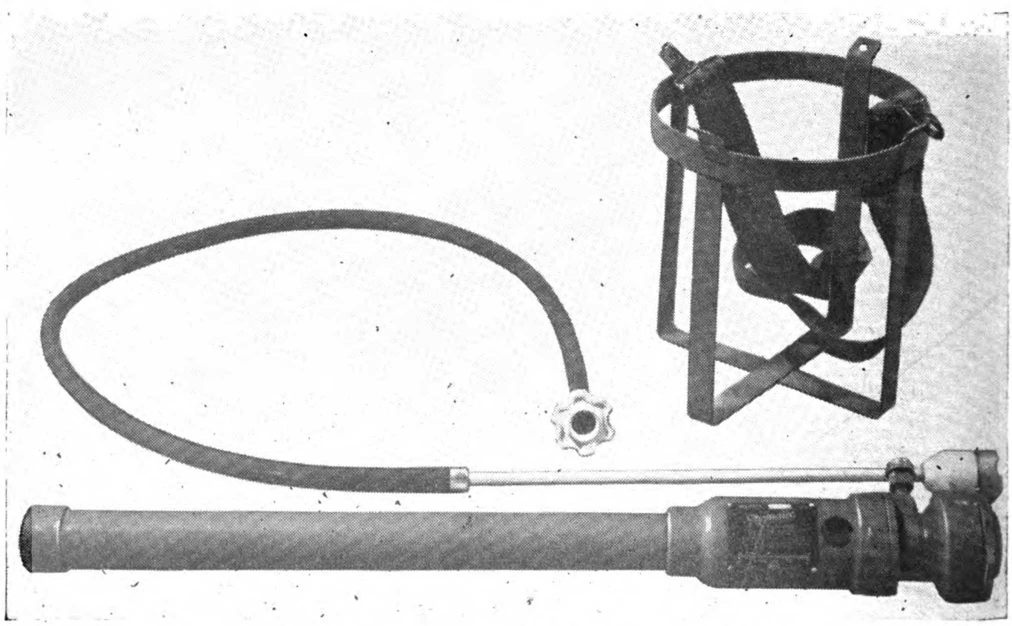


Figure 38. Foam applicator nozzle with hip pack.

a momentary stoppage of foam flow by puncturing a new can of foam solution and replacing the empty container in the sling carrier. Foam liquid is furnished in convenient 2-gallon containers. Foam applicator nozzles are furnished in two types which are similar, except that orifices are designed to accommodate proper discharge quantities at either high pressure or low pressure, thus permitting their use with either crash or fire trucks or trailers.

e. Nozzle maintenance. Extreme care should be taken to keep gaskets in all female thread insets. Gaskets should not protrude into the inside waterway; otherwise, maintenance of nozzles involves frequent inspection and cleaning, with necessary adjustment to keep shut-off valves and other working parts operating freely but not so loose that they will open or close through vibration. Care should be taken to avoid nicking nozzle tips since the slightest indentation or protrusion, particularly at the tip, will completely destroy the character of the stream and will cause it to "feather."

39. ADAPTERS AND COUPLINGS (fig. 39). **a. Double male.** Double male couplings have two ends, each with standard 2½-inch male fire hose threads. The principal use for double male couplings is to connect two female ends of hose or to connect nozzles or other appliances with female threads to female hose coupling threads.

b. Double female. Double female couplings are similar to double male couplings, except that they have swivel type female threads at each end and are used for connecting two male hose threads together. Double female couplings come in two standard sizes: 2½-inch and 4½-inch. The 4½-inch double female coupling is used to connect hard-suction hose from pump to hydrant.

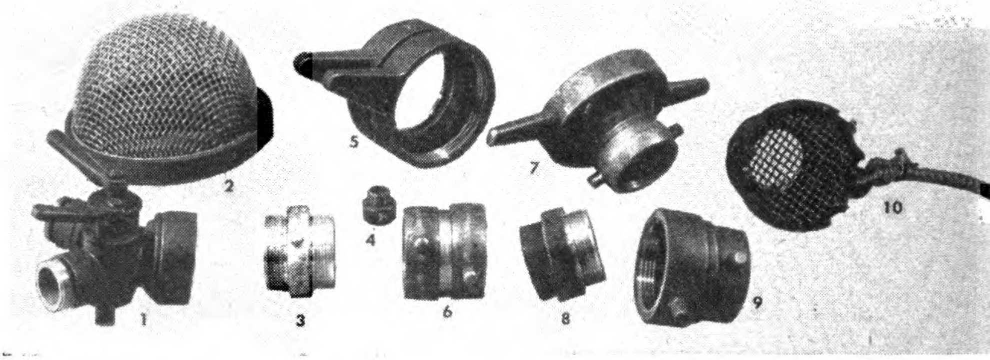
c. Reducing couplings. Reducing couplings are similar to double female couplings except that the two female ends have different thread sizes. Normal supply to fire-fighting organizations includes a 3-inch to 2½-inch standard hose thread reducing coupling for connecting 3-inch hard-suction hose to 2½-inch hydrant threads, and a 4½-inch to 2½-inch reducing coupling for connecting 4-inch hard-suction hose to 2½-inch hydrant threads.

d. Adapters. Special adapters are provided for converting from ¾-inch standard iron pipe thread to ¾-inch standard garden hose thread and for converting from 2-inch iron pipe thread to 2½-inch standard fire hose thread. Other adapters to convert standard equipment to fit odd local threads which may be encountered can readily be improvised by welding or brazing into a single double-end adapter fitting containing the appropriate threads.

e. Siamese. Siamese connections with a single swiveled 2½-inch female end and two 1½-inch male ends, each with individual valves,

also are provided with class 325 and class 1000 fire trucks and trailers. Gated siamese connections are used mainly to connect two 1½-inch hose lines to be fed through a single 2½-inch hose line from the source of supply.

f. Suction strainer. Suction strainers have 2½-, 3-, and 4½-inch female hose threads for attachment to the male end of appropriate suction hose. Whenever water is being drafted from a source of static water supply, suction hose strainers should be attached to prevent foreign material entering the pump. Ropes are fastened permanently to the ends of strainers to permit proper placement and securing of suction hose. Methods of locating suction hose are given in paragraph 19b.



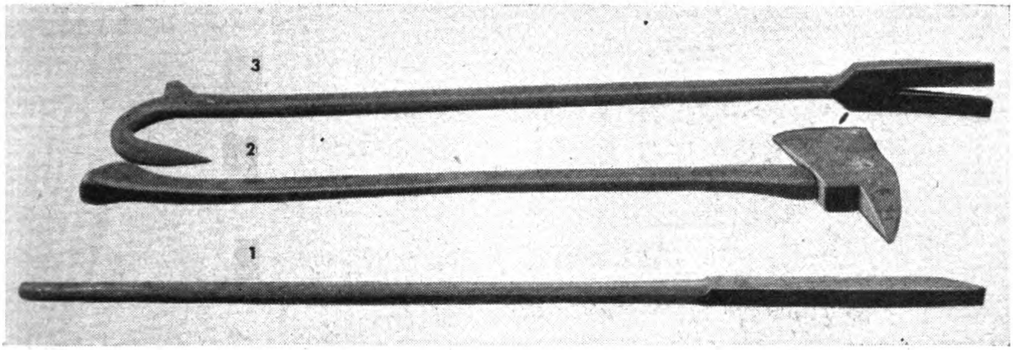
1. Gated siamese connection.
2. 4½-inch suction strainer.
3. Double male coupling.
4. Male-female adapter.
5. 4½-inch double-female coupling.
6. 2½-inch double female coupling.
7. Double male reducing coupling (4½-inch to 2½-inch).
8. Male-female coupling.
9. Double-male reducing coupling (3-inch to 2½-inch).
10. Suction strainer with retaining rope.

Figure 39. Fittings.

40. ENTRY TOOLS (fig. 40). **a. Crowbar.** Straight crowbars with one wedge-shaped end are furnished for entry, prying, lifting, and other work requiring considerable leverage.

b. Clawbar. The clawbar or wrecking bar, one end of which is wedge-shaped and the opposite curved and pointed, is furnished for lighter entry work where prying or forcing is the principal function. Clawbars are extremely useful in removing flooring or paneling, and for pulling hasps and forcing locks.

c. Pickhead fire ax. The pickhead fire ax is an entry and cutting tool. The sharp pick point is used for prying floor boards or sheathing and for removing brick, mortar, and plaster.



1. Crowbar.
2. Pickhead ax.
3. Clawbar.

Figure 40. Entry tools.

41. DIGGING TOOLS (fig. 41). **a. Round-point, short D-handle shovel.** The round-point, short D-handle shovel is carried on smaller vehicles where space is at a premium. It is used for all types of digging operations, particularly where they must be carried on in close quarters and where a long-handled shovel would be cumbersome and awkward. The round-point shovel is for digging and clearing suction pits, erecting earth barricades to confine water or burning liquids, constructing fire trails and barriers and for extricating mired equipment.

b. Square-point, short D-handle shovel. The square-point, short D-handle shovel is not a digging tool but is used as a scoop to clear and remove debris, dispose of water residue, and for other similar purposes. The D-handle is convenient for indoor use where most such work will be accomplished.

c. Round-point, long-handle shovel. The round-point, long-handle shovel is used for purposes similar to the round-point, short D-handle shovel, but is preferred whenever space permits, since it is less fatiguing.

d. Mattock. The mattock is used primarily to clear underbrush, remove root stubble and to break ground, particularly in connection with making fire barriers in forestry or brush fire work. It is useful also in the removal of heavy timbers.

42. LIGHTS AND LANTERNS (fig. 42). **a. Hand flashlight.** Standard two-cell, dry-battery pocket or belt flashlights are provided each fire fighting section for general purpose lighting use.

b. Wet-cell floodlight. Wet-cell, storage-battery type floodlights are provided with each crash truck and trailer section to floodlight fire-fighting and rescuing operations.

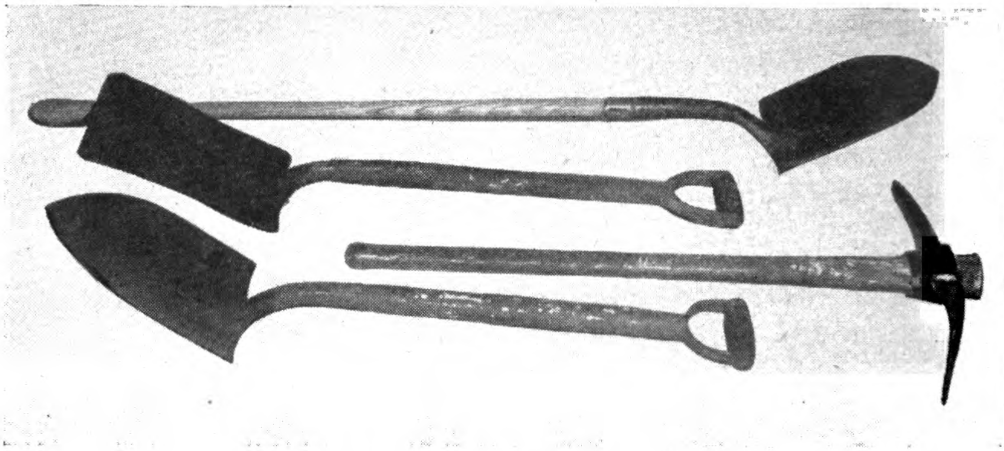


Figure 41. Digging tools.

c. Dry-cell spotlight and floodlight. In addition to the wet-cell type of floodlight, a special pistol grip type combination spotlight and floodlight, operating from dry-cell batteries, is provided with each crash truck section.

d. Electric lantern. Railroad type electric lanterns, operating from dry-cell batteries, are furnished with each truck and trailer section. Fire fighting will not require as much lighting as is needed in crash operations. Electric hand lanterns can be hung over the arm, leaving both hands free for other purposes.

1. *Electric hand lantern.*
2. *Dry-cell floodlight.*
3. *Spotlight bracket.*
4. *Vehicle spotlight.*
5. *Dry-cell battery.*
6. *Flashlight.*
7. *Wet battery.*
8. *Ground rod.*
9. *Hand spotlight.*
10. *Spotlight cord.*

Figure 42. Lights and lanterns.

e. Spotlight. Spotlights furnished with fire-fighting equipment sets Nos. 1 and 2 are intended for mounting on vehicular equipment not equipped with them. Spotlights so mounted are used for lighting the fire area or the inside of hose or equipment carrying vehicles.

43. FIRST-AID KIT (fig. 43). A standard 24-unit first-aid kit is furnished each fire-fighting section. The kit contains the necessary materials for first-aid treatment of cuts, burns, and fractures resulting from fire-fighting operations.

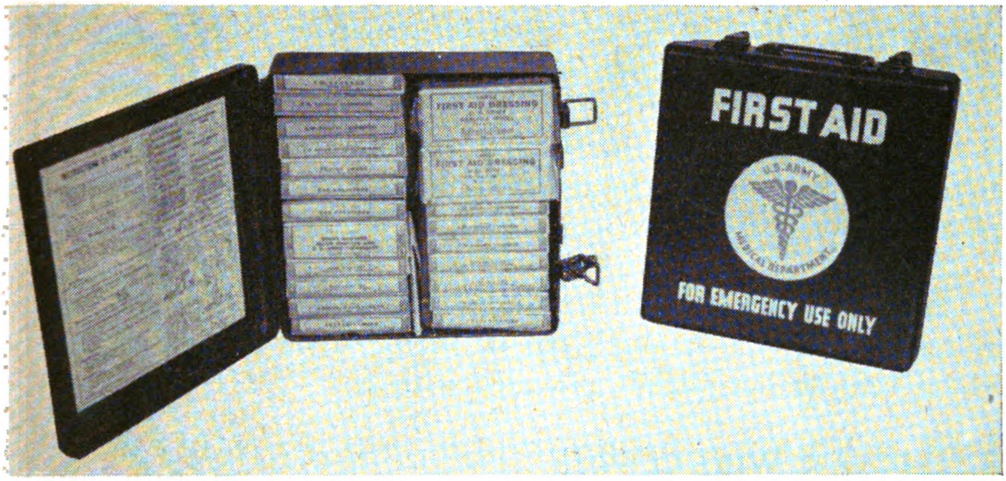
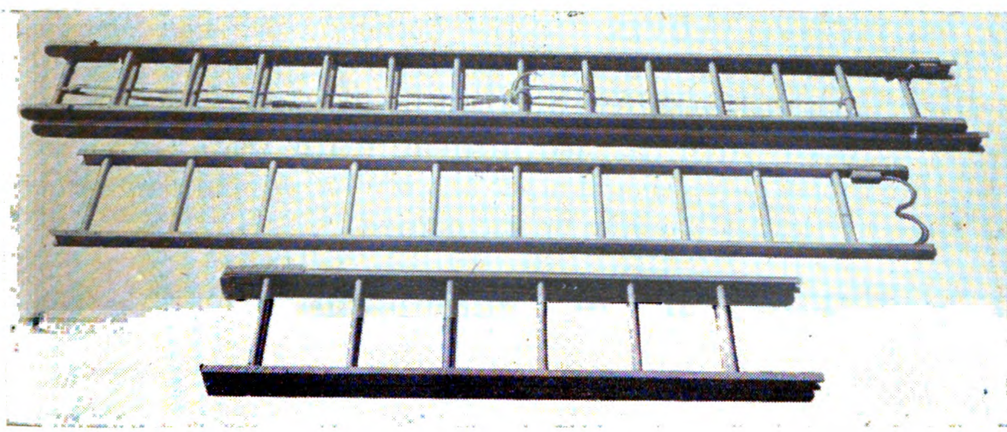


Figure 43. Twenty-four-unit first-aid kit.

44. LADDERS (fig. 44). **a. Sixteen-foot combination folding ladder.** This ladder is furnished with each crash truck and is used to gain access to engine-housing or cabins or the upper portions of airplanes. It can be erected as either a stepladder or an extended straight ladder.



1. *24-foot extension ladder.*
2. *12-foot roof ladder.*
3. *16-foot combination ladder.*

Figure 44. Ladders.

b. Twenty-foot extension ladder. The extension ladders are provided with each fire-truck section to reach, enter, or extend hose lines to locations above the ground level.

c. Twelve-foot roof ladder. The 12-foot roof ladder, with folding hooks at one end, is furnished with fire truck sections. This ladder is for operations on a sloping roof, the ladder being made secure by catching its hooks over the ridge of the roof.

45. PIKE POLE. Pike pole having iron or steel boathook-shaped ends and 8- or 10-foot pole handles are furnished with each fire and crash truck section. Pike poles are used for removing ceilings and side-sheathing, breaking windows, or other pull-down work.

46. ROPE. $\frac{3}{4}$-inch rope in 50- and 100-foot coils is furnished with each fire-fighting section for general purpose hoisting or pull-down operations, for rescue lines, and roping off fire areas.

47. ELECTRIC SIREN. An electric siren is furnished with fire-fighting equipment sets Nos. 1 and 2, to be mounted on $\frac{1}{4}$-ton, $\frac{3}{4}$-ton, or $1\frac{1}{2}$-ton vehicles not already provided with it.

48. ELECTRIC WIRE CLIPPER. The electric wire clipper is used for cutting and removing fallen wires. Clippers are furnished with a special search hook to facilitate placing the wire between the cutting jaws without direct contact with the operator; handles are specially insulated against high voltages. Wire cutters should never be used on electric power wires without the operator wearing special rubber and leather protective gloves.

49. PROTECTIVE GLOVES. Special lineman type, high dielectric strength rubber gloves with leather protective gauntlets are furnished to afford protection when operating around live wires. These gloves should be dried, powdered, and carefully stored when not in use. Protective rubber gloves should never be worn for this purpose without the protective leather gauntlet on the outside.

50. BOLT CLIPPER. Bolt clippers are provided for cutting bolts, heavy reinforcing bars, small pipes, and other metallic obstructions, principally in connection with entry and rescue operations.

CHAPTER 4

TACTICS AND TECHNIQUE OF FIRE FIGHTING

SECTION I

ELEMENTARY CHEMISTRY OF FIRE

51. OXIDATION. a. General. Oxidation is a reaction in which oxygen combines with some other substances. It does not necessarily mean giving off heat. In fact, the oxidation of the gas nitrogen requires the addition of great quantities of heat supplied by an electric arc. This reaction is sometimes referred to as negative oxidation.

b. Combustion. When the oxidation reaction is positive, it is termed combustion. In combustion, oxidation sometimes proceeds so slowly that light is not visible. However, heat and various gases always are products of combustion. Rapid combustion is termed burning, or fire. When combustion becomes extremely rapid, it is termed an explosion. This type of explosion should not be confused with a pressure explosion, which is the bursting of a container.

c. Spontaneous heating. When combustion is speeded up by confining the heat produced from the action of the substance, or when external heat is applied to the substance, the action is termed spontaneous heating. For example, if a ball of waste is saturated with vegetable oil or a substance which oxidizes rapidly, and is exposed to the air at ordinary temperature, it quickly heats spontaneously because the interwoven threads which make up the waste tend to confine the heat. In the second instance, if a high-pressure vessel containing gasoline is heated to a high temperature, flame appears when the resulting vapor is exposed to the air. The spontaneous ignition point is sometimes referred to as the self-ignition point.

d. Spontaneous ignition. The spontaneous ignition point is the temperature of a material taken at the instant heated combustible gases are produced in sufficient concentration that when exposed to oxygen they ignite spontaneously without the presence of an open flame. The material may be a gas, or it may be changed to gas before the spontaneous ignition point is reached.

e. Flash point or kindling point. The flash point is a term usually applied to liquids, and the kindling point to solids. Each term has the same definition. It is the temperature of the material taken at the instant combustible gases are produced in sufficient concentrations to flash momentarily when exposed to open flame.

f. Fire point or burning point. The fire, or burning point of a material is the temperature of the material taken at the instant the heated combustible gases are produced and maintained in sufficient concentration to perpetuate the action after ignition.

g. Burning limits. The burning limits of materials are the lower and upper limits of flammable vapor concentrations produced from the material during the stage of combustion.

Example: When the vapor concentration is dense some of the air is crowded out of the area and the vapor-air mixture is said to be above its upper burning limit or too rich to burn. The vapor space above materials which have low flash points is usually found in this condition if the vapors are confined. On the other hand, when the vapor density is low, flame will not propagate through the mixture, since the space between the vapor particles is increased to the extent that heat is not transmitted in sufficient quantities to continue the action. The mixture is said to be below the lower burning limit. Between the upper and lower burning limits, the speed of the burning action varies. In the center, the action is at its greatest speed and this condition is termed "explosion."

h. Explosion. An explosion is defined as instantaneous combustion. Explosions occur after vapors have been accumulated by oxidation and have been mixed to correct proportions with oxygen and then ignited. It is possible for an explosion to occur while various dusts are burning, when the center of the burning limits are reached. When dust is burning, the outside surface of the particles is increased, allowing more heat to contact them and produce vapors in large quantities. This mass production of flammable vapors soon reaches the explosive range.

52. EVOLUTION OF HEAT. a. General. Evolution of heat deals with two things—energy and matter. Matter consists of small particles, called molecules. For the purpose of explanation, there are as many molecules in a glass of water as there are glasses of water in the ocean.

Molecules are constantly in motion at temperatures above absolute zero, which is —459.6° F. This motion is vibratory, and as the intensity of the vibrations is increased the cohesive forces of the substance lessen.

b. Substance. A particular kind of matter is called a substance, and is identified by its density, conductivity, solubility, hardness, color, and other characteristics.

c. Energy. Energy is the ability or capacity to do work. There are many forms of energy such as heat, electrical, and chemical. A radiant source of heat creates a disturbance in the ether. When this disturbance, or wave, strikes any substance it produces heat energy. Transmission of heat by this means is termed radiation. The molecules of substances affected by radiation can receive and retransmit this energy to other molecules in the same substances, or to other substances in close proximity. The ability to receive and retransmit energy depends upon density, conductivity, solubility, and color of the substances. This limits the extent of the vibratory motion of the molecules to a certain definite space. The force that confines the action is called cohesion. This force is greatest in solids, lower in liquids, and lowest in gases. Substances may reflect, transmit, or absorb radiated energy.

d. Radiation exchange. All substances radiate energy at all temperatures above absolute zero. The hotter the body, the greater its radiation. Furthermore, all substances receive radiation from other substances. This exchange of radiant energy goes on continuously. Accordingly, a substance that remains at a constant temperature has not stopped radiating energy but is receiving energy at the same rate that it loses it by radiation. A substance that is a good radiator of energy is also a good absorber of energy. A black rough-surfaced body, is an excellent radiator as well as an excellent absorbent of radiant energy. Temperature is the condition of a substance which determines the direction of the flow of heat. Heat always flows from high to low temperatures. The colder substances always absorb heat.

53. TRANSMISSION OF HEAT. The transmission of sensible heat, that which is produced from molecular friction, takes place by conduction or convection. Conduction applies to heat transfer in solids and convection applies to heat transfer in liquids and gases.

Example: A burning match radiates heat energy equally in all directions. When the molecules of the wood vibrate and produce heat, it is said the heat is *conducted* through the wood. When the molecules of the vapor vibrate and produce heat, this heat is transferred by *convection.* As wood is a poor conductor of heat, the convection currents of the vapors carry away most of the heat. Most of the heat is convected above the match through the vapors since heat vapors and

the surrounding heated air will rise. Another match placed below, or at the side of, the lighted match will not ignite as quickly as when it is placed above.

54. GASES AND VAPORS. When matter is found at normal temperatures to be a gas, it is so termed, but when a solid or liquid is changed to a gas by the application of heat, this gas is called a vapor. Oxygen is a colorless, odorless, and tasteless gas. Oxygen does not burn, but supports combustion when it unites with a combustible gas or vapor. The air normally contains about 20.8 percent oxygen, the remaining 79.2 percent consisting of incombustible nitrogen and various other gases. Air containing 16 percent oxygen will not support flame and when the oxygen content is reduced to 10 percent, the air will not support life. Oxygen is soluble in water and is found in fresh water in quantities of approximately 3 volumes of oxygen to 100 volumes of water. This explains how fish are able to live in water and why fire fighters obtain oxygen near a flowing stream of water when working in a smoke-filled building.

55. THE LAW OF CONSERVATION OF ENERGY. The law of conservation of energy and matter states that neither energy nor matter can be destroyed, but that they can be changed from one form to another. When a house burns, one would naturally think that the matter contained in the house had been destroyed because the residue is smaller and weighs less than the house did, but if the ashes and the materials that had escaped as gases were weighed it would be found that no weight had been lost.

56. ELEMENTS OF FIRE. a. The elements necessary to create and maintain a fire condition may be graphically described as follows:
(1) The first element essential to the presence of fire is a burnable substance such as coal, wood, paper, or cloth. This fuel may be represented in graphic diagram as a single horizontal line (fig. 45(A)).
(2) To have fire, the fuel must be in the presence of heat, which is represented in figure 45(B) as a single diagonal line extending from the horizontal fuel line.
(3) Application of heat tends to decompose a combustible material and create a burnable gas or vapor. The reaction may be represented as shown in figure 45(C).
(4) Still a third element—the presence of air or oxygen to complete the oxidation process and maintain combustion—is needed to complete the burning phase. This third element, added to the other two elements, is represented in figure 45(D).

(5) These three elements, in contact in proper proportions to form the graphic triangle, will result in a fire (fig. 45(E)).
(6) Since these three elements are required to support a combustion condition, the removal of any one will destroy the combustion condition (fig. 45(F)).
(7) Likewise, the presence of the three elements in improper proportions or degree will fail to complete the graphic triangle and will not support a condition of combustion (fig. 45(C)).

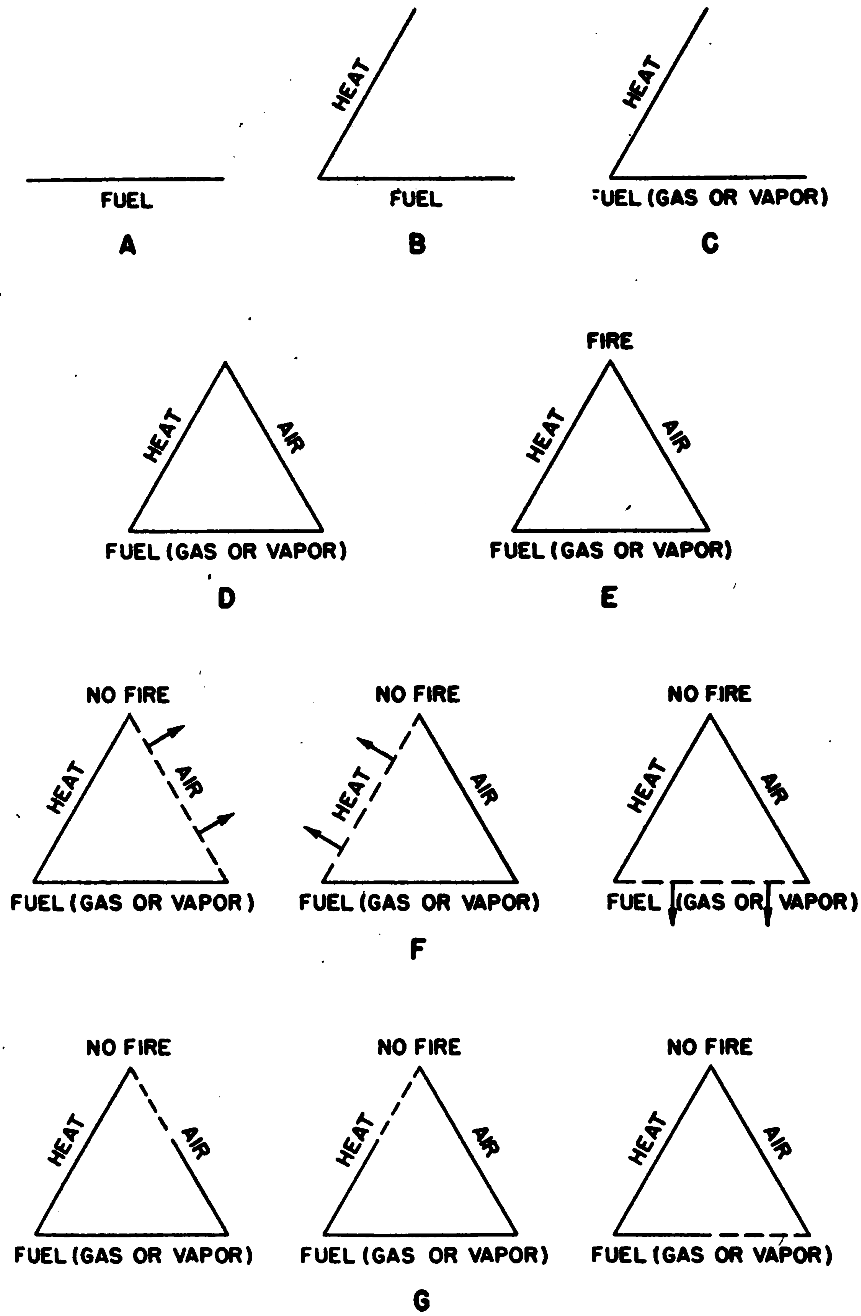


Figure 45. Elements of fire.

b. It is readily seen that the principles involved in controlling or extinguishing fire involve controlling or removing any one or more of the critical elements essential to combustion:

(1) Fuel is reduced or removed by disintegration through the process of burning, or is physically removed from contact with the other two elements, as when a burning log is removed from a fire.

(2) Heat is reduced or removed by the cooling and quenching effect of water, or a similar extinguisher applied to the fire. The fuel and the oxygen remain in contact, but the necessary heat has been removed.

(3) Oxygen is reduced or removed by the smothering action of foam, carbon dioxide gas, carbon tetrachloride vapors, or by a physical blanket or cover placed over the fire. Carbon dioxide gas and carbon tetrachloride vapors displace the oxygen in the surrounding air and, since these gases do not themselves support combustion, the fire condition is removed.

57. PROPAGATION OF FIRE. **a.** Flammable materials may be ignited in some manner and pass into the state of combustion. The heat produced by this action is absorbed by adjacent parts of the material producing flammable gases or vapors. These vapors are united with oxygen and, when in sufficient concentration, they are ignited by the flame. Heated flammable vapors and air rise and their definite directions of travel within a building are up, out, and down. During the propagation of a fire, vapors are produced which are not in sufficient concentration to be ignited by the flame. These vapors rise out of reach of the flame to the ceiling of the room, then spread out across the ceiling, producing what is termed by fire fighters as a "mushroom effect." The vapors then pass down to the door opening and from there may proceed to a stairway or elevator shaft.

b. Concentrated vapors collect at the topmost portion of the building or room and form a sufficient concentration to ignite when there is heat at this point. It may be that the spontaneous ignition point of the material in this portion of the building is lower than that of the vapors produced from below. If this is the case, the vapors produced from the material in the upper portion of the building have a lower ignition point than the vapors produced from below. Under these conditions, the vapors produced from the material in the upper portion of the building may ignite spontaneously from the heat produced from below.

c. If the material in the upper portion of the building is not combustible and the vapors produced are slow in reaching the concentration required for combustion, the mushroom condition may spread over the entire upper floors of the building. When these heated

vapor-air mixtures come in contact with the flame from below and are in sufficient concentration for burning an explosion usually occurs. This is followed by intensely rapid combustion called conflagration. When solid material has been subjected to great heat it quickly disintegrates to an ash; vapors rise rapidly, and a draft is created by cold air taking its place. This draft picks up portions of disintegrated material and distributes it to other portions of the building, or to other buildings where it contacts other combustible material, heating this material to the burning point and further extending the fire.

SECTION II

HYDRAULICS OF FIRE FIGHTING

58. GENERAL. a. Definition. Hydraulics is the branch of science or engineering which treats of the properties of water or other liquids at rest or in motion.

b. Properties of water. To understand the application of hydraulics in fire-fighting service, it is necessary first to recognize the basic physical properties of water at rest. Water may be considered as incompressible; it may be assumed that a given volume of water will always have the same weight and a given weight of water will always occupy the same space or volume. Water with mineral content and water at different degrees of temperature will vary so slightly from this rule, that the variation may be neglected.

(1) One cubic foot of water by volume weighs approximately 62.425 pounds. For simplicity, 62½ pounds usually is used.

(2) One pound of water occupies a volume of 27.648 cubic inches.

(3) There are 231 cubic inches in one U. S. Standard gallon of water.

(4) One gallon of water weighs 8.35 pounds.

(5) One cubic foot of water contains 7.481 U. S. Standard gallons.

59. AREA OF PLANE SURFACES. In the solving of practical problems in the fire service, it is necessary to obtain the areas of squares, rectangles, and circular plane surface.

a. The area of a *square* is obtained by multiplying its width by its height.

b. The area of a *rectangle* is the product of its width by its height.

c. The area of a *circle* equals the square of the diameter times .7854.

60. TO DETERMINE CAPACITY OR VOLUME. *Volume,* as applied to the fire service, is space included within the bounding surfaces of square, rectangular, or circular containers. Capacity or volume of various containers may be determined as follows:

a. The volume of a cube or a rectangular container is the product of length by width by height.

Find the volume of a rectangular container 14 feet long, 10 feet wide, and 9 feet high:

$$\begin{aligned} q &= lwh \\ l &= 14 \\ w &= 10 \\ h &= 9 \\ lwh &= 14 \times 9 \times 10, \text{ or } 1260 \\ q &= 1{,}260 \text{ cubic feet.} \end{aligned}$$

b. The volume of a cylindrical container is the product of the diameter squared by .7854 by height.

Find the volume of a cylindrical container 14 feet in diameter and 22 feet high:

$$\begin{aligned} q &= D^2\ .7854\ h \\ D &= 14 \\ D^2 &= 14 \times 14, \text{ or } 196 \\ h &= 22 \\ D^2 \times .7854\ h &= 196 \times .7854 \times 22, \text{ or } 3386 \\ q &= 3386 \text{ cubic feet.} \end{aligned}$$

61. HEAD. **a.** Head is the vertical distance between the surface of the water source and the point being considered. For example, if the vertical distance between the surface of the water in a tank and the hydrant outlet is 60 feet, the head of water at the hydrant is 60 feet.

b. Water pressure is proportional to its depth, and usually is stated in pounds per square inch. A cubic foot of fresh water weighs 62.5 pounds; it might be thought of as 144 columns, each 1 square inch in area and 1 foot in height. The total weight (62.5 pounds) divided by 144 equals .434 pounds, the weight of a column of water 1 square inch in area at its base and 1 foot high. Hence, pressure equals .434 times head. In terms of square inches the pressure at the base of a column of water is equal to the weight of the water in the column divided by the number of square inches of area in the base of the column. Since a column of water 1 square inch in base area and 1 foot high weighs .434 pounds, the effective pressure in pounds per square inch at any point in a column of water is equal to .434 times the height of the column above that point in feet, expressed as: $P = .434\,H$.

c. Static pressure is the pressure exerted by water at rest. The static pressure may be determined readily if the head is known.

$$SP = .434\ H.$$

d. Back pressure is the term used to indicate the pressure in pounds per square inch exerted by a head of water against a pump lifting it to an elevated point.

$$BP = .434\ H.$$

62. FLOW. **a.** Velocity flow is the rate of movement of water through hose and nozzles. This rate of movement is generally expressed in feet per second but may be expressed in inches per second or per minute. The velocity of a stream as it passes from an opening depends upon the pressure or head of the water causing the flow. Velocity flow for any given effective head or pressure is constant, regardless of the size of opening or orifice.

b. Velocity flow in feet per second, when head is known, is calculated by the formula: $V = 8\sqrt{H}$. For example, if the head is 121 feet:

$$\begin{aligned} V &= 8\sqrt{H} \\ H &= 121 \\ \sqrt{H} &= \sqrt{121}, \text{ or } 11 \\ 8\sqrt{H} &= 8 \times 11, \text{ or } 88 \\ V &= 88 \text{ feet per second.} \end{aligned}$$

c. Velocity flow in feet per second when pressure is known may be determined by the formula: $V = 12.1\sqrt{P}$. For example, if the nozzle pressure is 65 pounds per square inch:

$$\begin{aligned} V &= 12.1\ \sqrt{P} \\ P &= 65 \\ \sqrt{P} &= \sqrt{65}, \text{ or } 8.06 \\ 12.1\ P &= 12.1 \times 8.06, \text{ or } 97.5 \\ V &= 97.5 \text{ feet per second.} \end{aligned}$$

63. DISCHARGE FROM FIRE-FIGHTING APPLIANCES. **a.** Rate of discharge is the quantity of water issuing from an opening in a unit of time and is calculated in gallons per minute (gpm).

(1) In computing rate of discharge two items must be considered:

(a) Area of opening.

(b) Velocity of flow.

(2) The basic rate of discharge formula is: discharge equals area times velocity, expressed as: $Dis = AV$. With nozzle, hose, and hydrant opening measurements in inches, the area is expressed in square inches.

(3) Solution of the velocity formula, $V = 12.1\sqrt{P}$, gives the flow in feet per second. This is changed to inches per second by multiplying by 12, and this in turn to inches per minute by multiplying by 60.

(4) The area in square inches, multiplied by the linear velocity flow in inches per minute, gives the discharge in cubic inches per minute. This, divided by 231, gives the discharge in gallons per minute.

(5) The formula in detail appears as follows:

$$gpm = \frac{(D^2\ .7854)\ (12 \times 60 \times 12.1 \times \sqrt{P})}{231}$$

(6) Certain of these values are constant. To simplify the formula, they are computed and give the constant 29.7; 30 is commonly used because it is convenient and gives sufficiently correct solutions for practical purposes.

$$gpm = 30\ D^2 \sqrt{P}$$

Problem: What is the discharge in gallons per minute from a 1⅛-inch tip with a 40-pound nozzle pressure?

$$\begin{aligned} gpm &= 30\ D^2 \sqrt{P} \\ D &= 1\tfrac{1}{8}, \text{ or } 1.125 \\ D^2 &= 1.125 \times 1.125, \text{ or } 1.27 \\ P &= 40 \\ \sqrt{P} &= \sqrt{40}, \text{ or } 6.32 \\ 30\ D^2 \sqrt{P} &= 30 \times 1.27 \times 6.32, \text{ or } 241 \\ gpm &= 241. \end{aligned}$$

b. Open hose butts. The formula established in a. above is based upon the flow of water from an orifice completely filling the cross-sectional area of that opening. Nozzles used in the fire service are especially designed to present a stream of complete cross-sectional area, practically uniform in pressure across the orifice. Flow from open-pipe butts does not completely fill the cross-sectional area of the openings and pressures or velocities vary considerably across the orifice, thus reducing the actual flow below that given in the formula for determining full flow. For practical purposes the flow from an open butt may be considered as 70 percent of that from a nozzle of equal size operating under the same pressure. Problems are solved by using the formula given in a(5) above and multiplying the result by 0.7.

Problem: The pressure at a 2½-inch open butt is 15 pounds. What is the discharge?

$$\begin{aligned} gpm &= 30\ D^2 \sqrt{P}\ .7 \\ D &= 2\tfrac{1}{2} \text{ or } 2.5 \\ D^2 &= 2.5 \times 2.5, \text{ or } 6.25 \\ P &= 15 \end{aligned}$$

$$\sqrt{P} = \sqrt{15}, \text{ or } 3.87$$
$$30\ D^2 \sqrt{P}\ .7 = 30 \times 6.25 \times 3.87 \times .7, \text{ or } 508$$
$$gpm = 508.$$

c. Hydrants. The discharge from a hydrant is calculated from the open hose butt formula, although the discharge from hydrants of different designs will vary from this slightly.

64. FRICTION LOSS. a. Cause. The flow of water through pipes and hose lines is retarded by friction caused by the rubbing of the water on itself and against the inside surface of the carrier. Friction, in addition to obstructions to flow, such as bends, contractions, Siamese connections and valves, reduces the total energy available to produce the discharge. Initial energy in the form of pressure and velocity is expended to overcome this resistance and is dispersed in the form of heat transmitted through the hose or pipe line to outer surfaces. The amount of energy so expended, represented by the difference between initial pressure and velocity and residual pressure and velocity, is known as friction loss.

b. Rules of friction. There are four fundamental rules governing friction in pipes and hose lines.

(1) All other conditions being equal, the loss by friction varies directly with the length of line.

(2) In same sized hose, friction varies approximately as square of velocity of flow.

(3) For same discharge, friction loss varies inversely with fifth power of diameter of hose.

(4) For a given velocity of flow, friction loss is independent of pressure.

c. Calculating friction loss. There are two methods of determining friction loss.

(1) When pressure gauge readings of both engine pressure and nozzle pressure are available the difference between the two readings indicates the loss of pressure due to friction assuming that the initial engine pressure and residual nozzle pressure are both taken at the same elevation.

(2) The formula, $F = 2\ Q^2 + Q$, based on quantity of water flowing and length of 2½-inch hose is sufficiently accurate for practical purposes.

F is the friction loss in 100 feet of 2½-inch hose.

Q is the flow in hundreds of gallons per minute.

Problem: What is the friction loss in 350 feet of 2½-inch hose when the flow is 260 gpm?

$$F = 2\,Q^2 + Q$$
$$Q = 260 \div 100, \text{ or } 2.6$$
$$Q^2 = 2.6 \times 2.6, \text{ or } 6.76$$
$$2\,Q^2 + Q = 2 \times 6.76 + 2.6, \text{ or } 16.1$$
$$F = 16.1 \text{ pounds per square inch.}$$

Friction loss in 350 feet = 16.1×3.5, or 56.4 pounds per square inch.

When the flow is less than 100 gpm the following formula is used:

$$F = 2\,Q^2 + \tfrac{1}{2}\,Q.$$

d. Friction factors. (1) The formulas given above are used in calculating friction loss in a single line of 2½-inch hose. To determine the friction loss in other lay-outs of hose use the factors given below.

Friction Factor

Single lines

Diameter	*Factor*
1½ inch	.074

Siamese lines of equal length

Number of lines	*Diameter*	*Factor*
2	1½ inch	.266
2	2½ inch	3.6

(2) These factors are based on the relation of friction losses in the various sizes and lay-outs of hose to the friction loss in 2½-inch hose. To determine the friction loss of another size or lay-out of hose of the same length as single line 2½-inch hose, divide the friction loss for a given quantity flowing through a 2½-inch hose line by the corresponding factor for the actual size as given in the table above. If the lines composing a siamese are of unequal length, average their length.

(3) A loss of 25 pounds is always allowed in all standpipe connections, regardless of the length or size of standpipe. This is the total friction loss in the standpipe and fittings, including the street siamese check valve and the outlet valve. It applies for any flow.

65. EQUIVALENT NOZZLE DIAMETERS. In certain problems in the use of water, it is necessary to determine the size of a nozzle to carry the same discharge as do two or more nozzles of known sizes, or the number of nozzles required to carry the discharge of a single larger one. The formula $CND = \sqrt{(D_1)\ 2 + (D_2)^2}$ is used to select nozzles of the proper size.

CND = the combined nozzle diameter.
D_1 = the diameter of the first nozzle.
D_2 = the diameter of the second nozzle.

Problem: Two $1\frac{1}{4}$-inch nozzles are in use on $2\frac{1}{2}$-inch lines, and it is desired to siamese these lines and substitute a single nozzle with an equal discharge capacity. What should be the size of the single nozzle?

$$
\begin{aligned}
CND &= \sqrt{(D_1)^2 + (D_2)^2} \\
D_1 &= D_2 \\
(D_1)^2 &= 1.25 \times 1.25, \text{ or } 1.56 \\
(D_1)^2 + (D_2)^2 &= 1.56 + 1.56, \text{ or } 3.12 \\
\sqrt{(D_1)^2 + (D_2)^2} &= \sqrt{3.12}, \text{ or } 1.76 \\
CND &= 1.76 \text{ inches.}
\end{aligned}
$$

NOTE: Use the nearest standard size or $1\frac{3}{4}$ inches. To determine the number of small diameter nozzles required to carry a discharge load equivalent to that carried by a single large nozzle, consult table I.

TABLE I. *Equivalent discharge capacities of nozzles*

Number of Nozzles	Nozzle Size (Inches) (The Equivalent Nozzle Size is Found in the Nozzle-Size Column Opposite the Number of Nozzles.)											
1	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2
2	7/8	1 1/16	1 1/4	1 3/8	1 5/8	1 3/4	1 15/16	2 1/8	2 5/16	2 1/2	2 5/8	2 13/16
3	1 1/16	1 5/16	1 1/2	1 3/4	1 15/16	2 3/16	2 3/8	2 5/8	2 13/16	3	3 1/4	3 1/2
4	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4
5	1 3/8	1 11/16	2	2 1/4	2 1/2	2 3/4	3 1/16	3 3/8	3 5/8	3 15/16	4 3/16	
6	1 1/2	1 13/16	2 1/8	2 7/16	2 3/4	3 1/16	3 3/8	3 11/16	4			
7	1 5/8	2	2 5/16	2 5/8	3	3 5/16	3 5/8	4				
8	1 3/4	2 1/8	2 1/2	2 13/16	3 3/16	3 9/16	3 7/8					
9	1 7/8	2 1/4	2 5/8	3	3 3/8	3 3/4	4 1/8					
10	2	2 3/8	2 3/4	3 3/16	3 9/16	4						
11	2 1/16	2 1/2	2 7/8	3 5/16	3 3/4							
12	2 3/16	2 5/8	3	3 1/2	3 15/16							

66. PLACING PUMPS FOR RELAY OPERATIONS. **a.** Where water must be delivered through extremely long hose lay-outs, efficiency of operation is obtained by using large-diameter hose or siamesed lines from the pump to reduce friction loss. Sometimes it is impracticable to use a single pump, and an additional pump is necessary at a suitable

position in the line. The formula $DBP = L \div 2 + 10$ percent, for use with 2½-inch hose, makes it possible to determine where to place the additional pump.

DBP = Distance between pumps.
L = Total length of line.

Problem: 2,400-foot hose line is to be used. What should be distance between pumps?

$$\begin{aligned} DBP &= L \div 2 + 10 \text{ per cent} \\ 2{,}400 \div 2 &= 1{,}200 \\ 10 \text{ per cent of } 2{,}400 &= 240 \\ L \div 2 + 10 \text{ per cent} &= 1{,}200 + 240 \text{ or } 1{,}440 \text{ feet} \\ DBP &= 1{,}440 \text{ feet.} \end{aligned}$$

b. When it is necessary to relay water a long distance and more than two pumpers are needed, divide the length of line by the number of pumps available and place them in the line accordingly. They should not be more than 1,500 feet apart. A delivery pressure of 70 pounds per square inch is maintained from pumper to pumper.

c. The effectiveness of relaying water through connected pumpers and hose is limited, decreasing with the length of line and the number of pumpers used. With inexperienced pump operators, relaying water through more than two connected pumpers with more than 2,500 feet of hose is impractical. When it is necessary to pump water over long distances direct the discharge from each pump through an open butt into a sump near the next pump in line. Each pump is free of the effects of adjacent ones and the delivery pressure and friction loss are lower. The last pumper in the line maintains only the nozzle pressure plus the friction loss in the hose. Shut-down of the last pumper does not affect the operation of the other pumpers.

67. COMPUTATION OF THE RISE OF WATER DURING DRAFTING. The compound gauge on the suction side of a pump indicates the vacuum in the suction system. The vacuum scale is calibrated in inches of mercury. The gauge reading in inches is converted to pounds of negative pressure by multiplying by 0.49 (the weight of 1 cubic inch of mercury in pounds). Since water rises 2.304 feet for each pound of pressure removed, the total rise is obtained by multiplying the negative pressure by 2.304. This process is expressed in the following formula:

$$h = 0.49 \times 2.304 \times IV$$

Where: h = height of water rise
IV = gauge reading in inches of vacuum

Simplifying: $h = 1.13 \times IV.$

Problem: To what height will water rise in a suction hose when the compound gauge indicates 15 inches of vacuum?

$$h = 1.13 \times IV$$
$$IV = 15$$
$$h = 1.13 \times 15\text{, or } 16.9 \text{ feet.}$$

Solving the formula gives the height to which water will rise under ideal conditions. In the field estimate that water will rise 1 foot for each inch of vacuum.

68. SELECTION OF SUCTION HOSE FOR DRAFTING. The volume of water desired, the distance it must be lifted, and the size of the threads on the pump intake determine the size of the suction hose used. Table II gives values by means of which the proper size and length of hose can be selected. Study of the table shows that when a long suction line is necessary, small hoses restrict the capacity of the pump. The figures are based on the ability of the pump to maintain a vacuum of 23 inches.

TABLE II. *Suction hoses for drafting*

Quantity of Water (Gallons per Minute)	Maximum Suction in Feet — Size of Suction Hose: 3-Inch	3½-Inch	4-Inch	4½-Inch	5-Inch	
300	16	20	22½	24	24½	3 lengths of suction hose
400	8½	17	20	22½	24	
500		12½	18½	20½	23	
600		7	15	19½	21	
700		4½	11	17	19½	
800			6½	14½	19	2 lengths of suction hose
900			6	11½	17	
1000				8	14½	
1100				7½	12	
1200				4	9½	
1300					6½	
1300	1 length of suction hose				9½	

69. PENETRATION OF FIRE STREAMS. To extinguish a fire, the stream of water must penetrate as far as possible into the building. For maximum penetration the stream must enter just above the window sill and continue until it strikes the ceiling. The penetration increases with the height of the ceiling above the sill. The more nearly horizontal the stream enters the opening, the farther it penetrates. In estimating penetration, it is assumed that the height of a story is 12 feet, that window sills are 3 feet above floor level, and that the stream travels in a straight line. With these factors determined, the proper position of the nozzle to get the desired penetration is determined by simple proportion.

Problem: It is desired that a stream of water penetrate 20 feet into the third story of a building. At what distance from the building should the nozzle be placed?

Since corresponding parts of similar triangles are proportional, the height of the ceiling above the sill is to the desired penetration as the height of the third floor window sill is to the desired distance from the building.

Stated in the form of an equation:

$$(12 - 3) : 20 :: (24 + 3) : X$$
$$9 : 20 :: 27 : X$$
$$9X = 27 \times 20$$
$$X = 27 \times 20/9, \text{ or } 60 \text{ feet.}$$

TABLE III. *Effective range of fire streams*

	Size of Nozzle									
	1-Inch		1⅛-Inch		1¼-Inch		1⅜-Inch		1½-Inch	
	Maximum Effective Range									
Pressure at Nozzle (Lb. per Sq. In.)	Vertical Distance (Ft.)	Horizontal Distance (Ft.)	Vertical Distance (Ft.)	Horizontal Distance (Ft.)	Vertical Distance (Ft.)	Horizontal Distance (Ft.)	Vertical Distance (Ft.)	Horizontal Distance (Ft.)	Vertical Distance (Ft.)	Horizontal Distance (Ft.)
20	35	37	36	38	36	39	36	40	37	42
25	43	42	44	44	45	46	45	47	46	49
30	51	47	52	50	52	52	53	54	54	56
35	58	51	59	54	59	58	60	59	62	62
40	64	55	65	59	65	62	66	64	69	66
45	69	58	70	63	70	66	72	68	74	71
50	73	61	75	66	75	69	77	72	79	75
55	76	64	79	69	80	72	81	75	83	78
60	79	67	83	72	84	75	85	77	88	80
65	82	70	86	75	87	78	88	79	90	82
70	85	72	88	77	90	80	91	82	92	84
75	87	74	90	79	92	82	93	84	94	86
80	89	76	92	81	94	84	95	86	96	88
85	91	78	94	83	96	87	97	88	98	90
90	92	80	96	85	98	89	99	90	100	91

70. RANGE OF FIRE STREAMS. The range of a fire stream is measured either horizontally or vertically. Maximum horizontal range is obtained with the stream at an angle of 30° with the horizontal. Maximum vertical range is obtained with the stream at an angle of 75° with the horizontal. Table III gives the maximum vertical and horizontal ranges at which commonly used fire streams operate effectively.

71. NOZZLE REACTION. Water issuing from a nozzle under pressure exerts energy in the form of reaction. This energy forces the nozzle backward as the stream itself goes forward, overturning heavy stream appliances unless they are braced properly. Men holding the nozzle must be careful lest they be drawn backward and the nozzle get out of control so as to injure them. The reaction in pounds may be determined by the formula:

$$\begin{aligned} NR &= 1.5\ D^2\ NP \\ NR &= \text{nozzle reaction} \\ 1.5 &= \text{a constant} \\ D &= \text{diameter of the nozzle} \\ NP &= \text{nozzle pressure.} \end{aligned}$$

Problem: What is the nozzle reaction on a 2-inch nozzle under 90 pounds pressure?

$$\begin{aligned} NR &= 1.5\ D^2\ NP \\ D &= 2 \\ D^2 &= 2 \times 2, \text{ or } 4 \\ NP &= 90 \\ 1.5\ D^2\ NP &= 1.5 \times 4 \times 90 \times 540 \\ NR &= 540 \text{ pounds.} \end{aligned}$$

72. SIMPLIFIED FIRE STREAMS. a. Definition of fire streams. A fire stream is the body of water which, discharged from a nozzle, reaches the base of a fire as a solid and continuous mass in possession of complete extinguishing power. A "good" fire stream is one which reaches the seat of the fire as an approximately solid mass, such that nine-tenths of it will pass through an imaginary circle 15 inches in diameter. A good fire stream, therefore, must leave the nozzle under sufficient pressure to reach the fire and still possess the desired characteristics. Review of table III indicates that for practical purposes the effective reach of fire streams in feet may be assumed as being 1¾ times the nozzle pressure at 20 pounds, 1½ times the nozzle pressure at 50 pounds, 1¼ times the nozzle pressure at 75 pounds, and equal to the nozzle pressure at 100 pounds. One-hundred-pound nozzle pressure is the maximum practical pressure to be controlled by hand. For ordinary

purposes nozzle pressures of 40 to 60 pounds on hand nozzles will fulfill all requirements for good fire streams. Nozzle tips ranging from ¾-inch to 1¼-inch diameter generally are used for 2½-inch hand hose lines.

b. Simplified friction loss and discharge factors. Table IV shows approximate friction loss in each 100-foot length of 2½-inch fire hose for common nozzle tips operating at 50-pound nozzle pressure together with corresponding approximate quantities of discharge. Friction loss expressed in pounds corresponds closely with figures which appear in each respective nozzle size, such as ¾-inch nozzle, 4 pounds; ⅞-inch nozzle, 8 pounds; 1-inch nozzle, 10 pounds; 1⅛-inch nozzle, 18 pounds; 1¼-inch nozzle, 25 pounds; thus lending to the use of this table as a rapid memory table. Discharge quantities for the respective nozzle sizes increase in increments of 50 gallons for each larger nozzle size. Friction loss in two 100-foot lines of 2 1.2-inch hose siamesed with a single nozzle is approximately one-quarter the loss in a single line of the same length.

c. Compilation of pump pressure. To determine the approximate pressure to be carried at the fire pump to produce a "good" fire stream, it is necessary to know the length of hose line involved, the size of the nozzle tip, and the approximate elevation of the nozzle tip with respect to the pump. Actually the pump pressure required will be equal to the sum of the friction loss in the total line, the difference in elevation or head converted to pounds as stated in paragraph 61, and the resultant nozzle pressure desired. Five pounds may be added or subtracted to compensate for each average story of height of the nozzle above or below the pump. When pumping into a standpipe connection an additional 25 pounds should be allowed to compensate for frictional losses in the standpipe.

Example: Find the required pump pressure to develop a good fire stream through a 1-inch nozzle and 300 feet of 2½-inch hose when the nozzle is at a height of two stories above the pumps.

(1) From table IV, friction loss is 10 pounds per 100 feet, or a total of 30 pounds.

(2) Add two stories, or 10 pounds, for elevation of nozzle.

(3) Add 50 pounds for desired average nozzle pressure.

(4) Desired engine pressure is equal to 30 plus 10 plus 50, or 90 pounds.

d. Master fire stream. So called "master" or "heavy" fire streams refer to fire streams through nozzle tips larger than 1¼ inches in diameter. Nozzle reaction of a fire stream of this size is too great to be controlled by hand. Such streams are usually supported on fixed monitors, turrets, decks, or deluge nozzles. Because of the increased

TABLE IV. *Approximate friction loss and discharge—2½-inch hand hose lines*

Nozzle size (inches)	Approximate nozzle pressure (pounds)	Approximate discharge gpm (pounds)	Friction loss (pounds per 100 feet)		
			Single 2½-inch line	Siamesed 2½-inch line	
¾	50	100	4	1	
⅞	50	150	8	2	
1	50	200	10	3	¼ loss in single line
1⅛	50	250	18	5	
1¼	50	300	25	6	

TABLE V. *Approximate friction loss and discharge—master streams*

Nozzle size (inches)	Approximate nozzle pressure (pounds)	Approximate discharge gpm (pounds)	Friction loss (pounds per 100 feet)						
			Single 2½-inch line	Two 2½-inch lines		Three 2½-inch lines		Four 2½-inch lines	
1¼	80	400	25	12	½ loss in single line	6	¼ loss in single line	3	⅛ loss in single line
1⅜	80	500	38	19		9		5	
1½	80	600	50	25		12		6	
1⅝	80	700	58	29		15		8	
1¾	80	800	75	38		19		10	
1⅞	80	900	87	44		22		11	
2	80	1,000	120	60		30		15	

mass of the stream from larger nozzles higher nozzle pressures may be used and still maintain the characteristics of a "good" fire stream. Nozzle pressures from 60 to 100 pounds are commonly satisfactory. Greater volume of discharge is supplied to such nozzles by two or more siamesed 2½-inch lines. The friction loss in a single line flowing such large quantities of water would be prohibitive. Table V shows similar approximate friction losses and quantity discharge for common heavy stream nozzles through single, double, triple, and quadruple siamesed lines operating at a nozzle pressure of 80 pounds per square inch. The discharge increases in increments of 100 gallons per minute, for each increase in size of nozzle. The basic friction loss in a single line readily is associated with the corresponding nozzle size, with proportional factors for the multiple lines. Problems in determining friction loss and pump pressure to serve master streams are solved like those involving hand lines.

e. Small hose lines. (1) Small hose, of ¾-, 1-, and 1½-inch diameter, and small nozzles from 3/16- to ¾-inch are particularly applicable to inside fire fighting, and through their use water damage at fires can be minimized. Because of the flexibility of such small lines and the ease with which they may be moved about they are equally valuable in extinguishing a considerable amount of fire on outside surfaces, such as roofs, side walls, and sheds, and in protecting exposures. The use of 1½-inch hose, both for a complete line and as an extension of 2½-inch hose, has increased rapidly, and it is now considered a standard item of equipment by most fire departments.

(2) The ¾- and 1-inch lines usually are used in connection with booster water tank service with 3/16- and ⅜-inch tips. These lines generally are of fixed length. A pump pressure of 80 to 100 pounds, depending upon the nozzle used, generally will provide a good stream. Excessive pressure may break up the stream, which in some applications may be desirable.

(3) For inside lines of 1½-inch hose, with ½- to ¾-inch tips, streams of great force are not desirable, but they must have sufficient reach and penetration to reach the fire from a distance of 20 to 50 feet. Nozzle pressures from 20 to 30 pounds are sufficient. For outside lines the stream should have a greater carry. Nozzle pressures from 30 to 50 pounds may be desirable. When 1½-inch hose is used as an extension to 2½-inch hose, the flow through the nozzle is so small that the resulting friction loss in the 2½-inch hose is negligible. Another common practice is to extend two 1½-inch lines from a single 2½-inch line by a wye connection. In this case double the flow will pass through the 2½-inch hose and the friction loss in the 2½-inch hose will be considerable, particularly if it is of any great length. Two 1½-inch lines

may be extended from a single 1½-inch line, but this lay-out is not recommended except for extremely short lines because of excessive friction loss in the single 1½-inch line.

(4) Table VI shows the approximate nozzle pressure desired, flow in gallons per minute, friction loss in pounds per 100 feet of hose, and the arbitrary pump pressure satisfactory for maintaining streams for various lay-outs of 1½-inch hose.

TABLE VI. *Approximate pump pressure for effective 1½-inch hose streams*

Short stretch—up to 300 feet. Medium stretch—300 to 600 feet. Long stretch—600 to 1,000 feet.		Nozzle pressures: Inside stream—25 pounds. Outside stream—40 pounds.						
	Layout	Nozzle size (inches)	Nozzle pressure (pounds)	G.P.M.	Approximate friction loss (lbs. per 100 ft.)	Approximate pump pressure: Short stretch	Medium stretch	Long stretch
A	Single line of 1½-inch hose	½	25	36	5	45	60	75
B		⅝	25	58	12	75	100	150
C	Direct—inside stream	¾	25	84	23	100	175	250
D	Single line of 1½-inch hose	½	40	47	8	75	100	125
E		⅝	40	73	18	100	150	225
F	Direct—outside stream	¾	40	105	36	150	250	400
G	Single line of 1½-inch hose extended from 2½-inch	½	Ignore loss in 2½-inch hose.			Same as A or D above.		
H		⅝	Ignore loss in 2½-inch hose.			Same as B or E above.		
I		¾	Add to C or F above—3 pounds per 100 feet of 2½-inch hose.					
J	Two lines of 1½-inch hose extended from 2½-inch.	½	Add to A or D above—2 pounds per 100 feet of 2½-inch hose.					
K		⅝	Add to B or E above—5 pounds per 100 feet of 2½-inch hose.					
L		¾	Add to C or F above—10 pounds per 100 feet of 2½-inch hose.					
M	Two lines of 1½-inch hose extended from 1½-inch.	½	Add to A or D above—20 to 25 pounds per 100 feet of single 1½-inch line.					
N		⅝	Add to B or E above—40 to 65 pounds per 100 feet of single 1½-inch line.					
O	Not practical except for extremely short lines.	¾	Add to C or F above—90 to 120 pounds per 100 feet of single 1½-inch line.					

SECTION III
TACTICS OF FIRE FIGHTING

73. FUNDAMENTALS OF FIRE-FIGHTING TACTICS. Fire-fighting tactics is the art of using manpower and equipment on the fire grounds. It is the method or procedure by which the officer in charge seeks to attack, control, and extinguish the fire.

74. GENERAL PROCEDURE AT FIRES. **a.** A good general procedure at most fires is as follows:

(1) Size up the situation.
(2) Conduct rescue operations.
(3) Cover adjacent structures.
(4) Confine fire.
(5) Extinguish fire.
(6) Overhaul premises.

b. Ventilation and salvage work are important. Their place in the above procedure varies with the situation.

75. SIZE-UP. **a.** In sizing up the situation, the officer or noncommissioned officer in charge decides upon the most effective plan for attacking the fire. This plan is determined by the character of the fire and the men and equipment at his disposal. The leader quickly considers such factors as life hazard, exposed buildings, combustibility of material, amount of fire, and water supply. Accessibility of the fire and condition of adjacant streets are important.

b. This plan is useless unless it is executed properly. A mediocre plan of attack, well executed, has more chance of succeeding than a brilliant plan poorly executed.

76. RESCUE. **a.** Rescue is the operation of removing human beings from burning buildings or aircraft to a place of safety. Rescue requires immediate action upon the arrival of the first section. Rescuers are protected by keeping their routes of escape free of fire.

b. Each officer, noncommissioned officer, and fire fighter must understand the principles governing rescue. The first questions regarding rescue are:

(1) Are there any people inside?
(2) If so, are they in danger?
(3) How can they be reached?
(4) What must be done to effect the rescue?
(5) Is additional help necessary?

77. COVERING EXPOSURES. The major problem of fire fighting is the exposure fire. An exposure fire is one that may extend to adjacent structures. An exposure fire which extends over a considerable area and destroys a number of buildings or a large amount of material is termed a conflagration. In an exposure fire, there may be a life hazard as well as a property hazard. The protection of life is given first consideration. Structures to which the fire may extend are evacuated promptly.

78. CONFINING THE FIRE. Confining the fire covers the operations which prevent the fire from extending to other parts of the burning building, material, or aircraft. Large open areas, such as those found in warehouses, hangars, and other large structures, offer little opportunity to confine the fire after it has gained headway. A vigorous water stream attack from inside the building is the best method of confining the fire.

79. EXTINGUISHING THE FIRE. No amount of water poured into the smoke will extinguish the fire. Men must be trained to get inside and deal directly with the source of the fire. The most important steps in extinguishing a fire are: first, locate the main body of fire; second, apply the necessary amount of water or other extinguishing agent to the *base* of the fire itself. A small amount of water or other extinguishing agent applied properly produces better results than a large quantity which does not reach the base of the fire. Either foam or fog may be used on oils and other inflammable volatile liquids. Fog distributed throughout the vapors being generated dilutes them, forms a partial blanket over the fire, and absorbs the heat of combustion. It combines the actions of cooling and smothering.

80. OVERHAULING. Overhauling, the last phase of the extinguishing operations, includes the measures taken to prevent the fire from rekindling and to leave the premises in a safe condition. All sparks and cinders are extinguished. Partitions into which the fire has spread are opened up and treated with water. In overhauling inflammable liquid fires, be sure that the liquid has been covered thoroughly with foam, to prevent a reflash or reignition. On a flat surface, such as a runway, the liquid may be washed to a less dangerous location by "sweeping" the area with streams of high-pressure water.

81. VENTILATION. Ventilation plays an important part in the attack, control, and extinguishment of building fires. Fire fighters cannot work inside a building until smoke, gases, and heated air have been reduced. A good rule is to have a charged line in position before

opening the building. A fire easily may get out of control if the building is opened before lines are ready for operations. Section IV treats ventilation more completely.

82. SALVAGE OPERATIONS. Salvage operations protect the building and contents from unnecessary damage due to water, smoke, and heat. Canvas covers and tarpaulins are spread over valuable machinery or supplies while the fire is being extinguished. Section V treats salvage operations more completely. Ventilation and salvage work may be performed either separately or along with the other duties for fire fighting, depending on the conditions at the fire.

83. FIRES IN EXPLOSIVES AND CHEMICALS. **a. General.** A fire involving explosives or ammunition may result in an intense conflagration or explosions. The first small blaze must be attacked immediately with whatever hand equipment is available. Due to the potential presence of explosives or chemicals in almost any fire that military fire fighting organizations may encounter, it is especially important to study the characteristics of all types of military matériel of this nature and to recognize its possible presence in any fire condition. For more complete details with respect to the characteristics of ordnance material and its storage and handling, including other fire conditions, reference is made to the following publications: Ordnance Safety Manual, OO Form No. 7224; TM 9–1900; and Ordance Department Safety Bulletin No. 26, Change No. 1.

b. Safety of fire fighters. Forces fighting fires of dangerous explosives or ammunition must seek all available cover. Personnel running from a fire may be injured seriously while others much nearer the danger escape injury because they have sought cover, even when it is only a tree or shallow ditch. It is foolhardy to rush into a possible danger zone without first investigating it. Fire-fighting equipment should be halted at least 200 yards from the burning building until the probable hazard has been determined.

c. Grass fires. Grass fires, even when close to stored explosives, are attacked vigorously by fire-fighting forces upon arrival. However, if the fire has gained great headway within the storage area, fire-fighting forces do not endanger themselves or their equipment in hopeless efforts to extinguish the fire. Instead, they devote their attention to saving adjacent buildings.

d. Chemical bomb fires. Fires in a chemical magazine require the removal of all personnel on the downwind side. If any large quantity of gas or smoke is likely to be released by such a fire, inhabitants located downwind are notified immediately. All personnel fighting the fire wear service gas masks.

e. Fragmentation bomb fires. Fires in a magazine in which fragmentation bombs are stored usually cause the bombs to detonate intermittently.

f. Demolition bomb fires. Fires in magazines containing demolition bombs usually result in mass detonation. If the fire has gained headway, no attempt should be made to fight it. The magazine is abandoned and the efforts of fire fighters are confined to preventing the fire from spreading. Fire fighters withdraw to a distance and utilize available cover or lie flat on the ground to protect themselves from explosions.

g. Pyrotechnic fires. Pyrotechnics sometimes ignite spontaneously if subjected to moisture and high temperatures. However, most pyrotechnics when wet become less sensitive and more difficult to ignite. An extremely hot fire is created by burning pyrotechnics, since practically all types contain some oxygen-bearing materials. It is difficult to put out such fires with water, although water tends to lower the temperature of the burning pyrotechnic and is recommended for fighting this kind of fire. Pyrotechnics such as airplane flares sometimes explode, but most other types burn with intense heat and without serious explosion.

h. Fires in blank ammunition, TNT, blasting caps, and dynamite. Fires in these materials are fought with caution. If the fire has gained headway, no attempt should be made to fight it. Efforts are confined to preventing the fire from spreading. The usual precautions are taken against injury from explosions.

SECTION IV
VENTILATION

84. VENTILATION. a. Ventilation is one of the major elements in fire fighting. The value of a fixed operating policy regarding ventilation often is underestimated by fire fighters; yet proper ventilation not only reduces fire losses but also reduces the actual physical punishment the fire fighters must undergo while extinguishing fires.

b. It is practically impossible to conduct any form of physical drill in ventilation. However there should be constant instruction in it. Actual fires offer the best training; ventilation should be practiced at every fire, regardless of its size.

c. Each building in the assigned area should be studied from a ventilation standpoint. Each building or structure is an individual problem. Similarly each fire is an individual problem; its size, extent,

and location, the susceptibility of the endangered material to smoke and heat damage, and the life hazard involved determine how it should be treated. When to break windows, chop holes in roofs, and otherwise damage the building or structure for the purpose of ventilation is a question for the officer or noncommissioned officer in command of the fire to decide according to the circumstances. Whether the building should be ventilated from the inside, partly from the inside and partly from the outside, or from the outside only, depends upon conditions.

d. Heat and hot gases of combustion travel vertically until they meet an obstruction, a ceiling or roof, then mushroom horizontally in all directions from the point of contact. Then, if they find an opening, no matter how small, they travel vertically again until they finally reach the highest point in the structure where they mushroom under the barrier and bank down into the confining space. The gases in this confining space, even though heated above their ignition temperature, may not ignite for lack of oxygen. However, admission of fresh air containing oxygen may cause the mixture to ignite with the force of an explosion. Such explosions are sometimes called "back drafts." They seldom occur unless there is a heavy fire in relation to the confining space, but the danger must constantly be considered when ventilating.

e. The object of ventilation is twofold. It draws the heat and smoke straight up through elevator or other shafts, and through the roof to the atmosphere, thus releasing the pressure and heat caused by the fire and thereby preventing the mushrooming of the fire on the various floors. Also, it draws away the heavy smoke and gases which may have backed down to the very seat of the fire, thus allowing the firefighters to operate to greater advantage and eliminating the danger of "back draft." Furthermore, ventilation assists in rescue work. It is essential to quick operations.

85. WINDOW VENTILATION. For ventilation through windows, open them two-thirds from the top and one-third from the bottom, on the lee side first. If there is an opportunity for cross draft, open them fully from the top on the lee side and fully from the bottom on the windward side. The cold air coming in from the bottom will cause the heated air to go out at the top quickly. Open the doors, if doing so permits smoke and heat to leave the structure or increases the air circulation for carrying the heat and smoke out through the windows; but close them if they merely permit the heat and smoke to travel to another part of the structure.

86. ROOF VENTILATION. In opening the peaked roof of building, make the opening on the lee side of the peak by ripping off the roof

covering and cutting the sheeting without damaging the rafters. Make the openings parallel to the peak of the roof and large enough to permit the greatest amount of heat and smoke to escape as quickly as possible.

87. BASEMENT VENTILATION. **a.** With a basement fire it may be necessary to cut holes in the flooring above to ventilate the building. Open the outside cellar doors and side windows to allow the heat and smoke to escape. Then cut holes in the flooring, near a window if possible and on the lee side. In any event, opening should be made to permit the fire fighters to get to the seat of the fire.

b. With extremely stubborn basement fires it is possible to accelerate the ventilation by concentrating streams at the front or rear of the building. Ventilate one end and advance with the hose lines to push the heat and gases toward the openings at the opposite end. If this is done, additional lines must be used to prevent the fire from spreading upward.

c. In opening a flat roof, make an opening over a stairway, ventilating shaft, or hallway by removing the roof covering and cutting or sawing the roof sheeting. Make sure that the opening is large enough to ventilate the structure quickly. Also probe the opening with a pike pole to be sure that a hanging ceiling is not impeding the heat and smoke. If the fire is immediately under the roof, the spot to be opened can be determined by the tar boiling over it or by its heat. Hot spots may be located by feeling with the bare hand.

d. Skylights may be removed or broken, or the metal holding brackets may be turned back and the glass lifted or slid out without damaging it. With sloping skylights, open the lee side first; usually the windward side is not opened.

88. PROCEDURE. When the command is given to ventilate, all possible openings that will let the heat and smoke out of the structure and all openings for allowing fresh air to enter it should be opened to set up an air current. At the fire station it is well to drill by actually opening the windows for the different situations outlined, just as though there were an actual fire in the buildings. In a building charged with heat and smoke, ventilating should proceed from the top downward. Open windows on each floor as necessary.

89. PRECAUTIONS. **a.** One of the precautions which must be observed in ventilating is not to open doors or windows or to make other openings which directly expose nearby property. Furthermore, never open up where the draft might draw the fire to endanger adjoining property. Make the openings so as to draw the fire away from danger points and to enable the fire fighters working on the fire to

cover the exposure and extinguish the fire. It may be necessary to make the openings some distance from the fire to protect the adjoining property and to draw the fire through a safer channel, for proper ventilation. Always note the direction from which the wind is blowing. Also estimate the fire and remember that quick and proper ventilation is one of the best means of controlling a fire quickly.

b. Theaters may have smoke vents over the stage which operate either automatically or manually. During theater fires these vents should be inspected to see that they are operating properly.

c. Never make openings or open door, windows, or stairways in such manner as to prevent persons from leaving building. Ventilation should assist escape, not hinder it.

d. Always see that a line of retreat is left open for emergencies. Never cut holes in aisles or passageways unless it is absolutely necessary. If holes are cut in aisles or passageways, they should be covered as soon as possible to prevent personnel from falling in.

e. When ventilating in heavy smoke or gases the men should work in pairs. If there is an accident injuring one man, the second is available to rescue him.

90. "BACK DRAFTS." When ventilating in large areas, be careful of "back drafts." Get to one side of doors or windows, stay low, and have a charged line in position before opening up. "Back drafts" are more pronounced where fires have been smouldering for a long time and gases have formed from incomplete combustion. When the firemen open a window or door, the additional air mixes with the heated gases to form an explosive mixture, or causes such rapid combustion as to start a heavy wave of air and smoke away from the fire. Ventilating operations started in time prevent "back drafts."

SECTION V
SALVAGE OPERATIONS

91. GENERAL. Often as much damage is done by the water used to extinguish a fire as by the fire itself. While the primary mission is to put out the fire, the fire fighter also prevents unnecessary damage to the contents of the burning building from water, smoke and heat. The amount of salvage work possible depends on the extent and nature of the fire, the construction of the building, the type of material stored therein, and the number of men and the salvage equipment available. Effective salvage requires a knowledge of the effect of water,

smoke, and heat on various materials, and of the proper use of salvage equipment.

92. EFFECT OF CONSTRUCTION AND STORAGE METHODS ON SALVAGE. **a. Construction.** Proper construction reduces the water damage and makes salvage more effective. Shelves built with a 2-inch space between the rear edge and the wall, and with at least 18 inches clearance at the top, can be covered with canvas. Water running down the wall passes harmlessly to the floor. Supplies stored on shelves built flush with the wall and up to the ceiling cannot be protected by salvage covers, and must be moved to prevent water damage.

b. Storage methods. Supplies subject to water damage, and those packed in paper cartons, are best stored on skids. The lower portions of piles of perishable supplies stacked directly on the floor cannot be salvaged when large quantities of water are used to extinguish the fire. The bottom tier of paper cartons becomes water-soaked, and collapses, allowing the entire pile to overturn onto the floor.

93. SALVAGE DURING THE FIRE. **a.** Supplies on lower floors are covered with salvage covers, or moved to another part of the building or out of doors. Machinery is covered to protect electrical devices and machined surfaces. Office records are placed off the floor and carefully covered with canvas.

b. All hose connections are made tight to prevent water leakage inside the building, and water streams are so directed as to avoid unnecessary wetting of supplies. Further damage by water is prevented by using sawdust to absorb the water and to form dikes which direct the water outdoors through doorways or through holes bored in the floor.

c. When fighting fires in absorbent materials, care must be taken to prevent the added weight of the water collapsing the floor. To estimate rapidly the weight of water being used, calculate "a pint a pound." For example, a single line of hose using a 1⅛-inch nozzle at 40 pounds pressure delivers about 237 gallons per minute. Since a gallon of water weighs about 8 pounds, the total weight added each minute to the floor is 8 times 237, or 1,896 pounds. Obviously, if all the water delivered is absorbed by stored materials, the added weight is likely to collapse the building.

94. SALVAGE AFTER THE FIRE. When the fire is extinguished, articles of value are removed from the debris. The debris is removed from the building, floors are swept, and excess water is removed with brooms and squeegees. Sawdust is sprinkled over the floors to absorb some of the remaining water and then is removed with shovels or

push brooms. Holes in the roof are covered with tarpaulins or roofing paper, all nails and sharp objects first being removed to prevent damage to the cover. When the entire roof is destroyed, it is replaced temporarily by using available lumber, or canvas truck covers, fastened securely to prevent wind damage.

95. DRAINAGE EXPEDIENTS. a. Catch basin (fig. 46). When drains cannot be made to carry off water dripping through a ceiling, a catch basin is constructed by placing a canvas cover over furniture, boxes, or bales arranged in a circle or square. The tarpaulin is fastened at the sides, with the bottom of the basin resting on the floor. Water is removed by bailing.

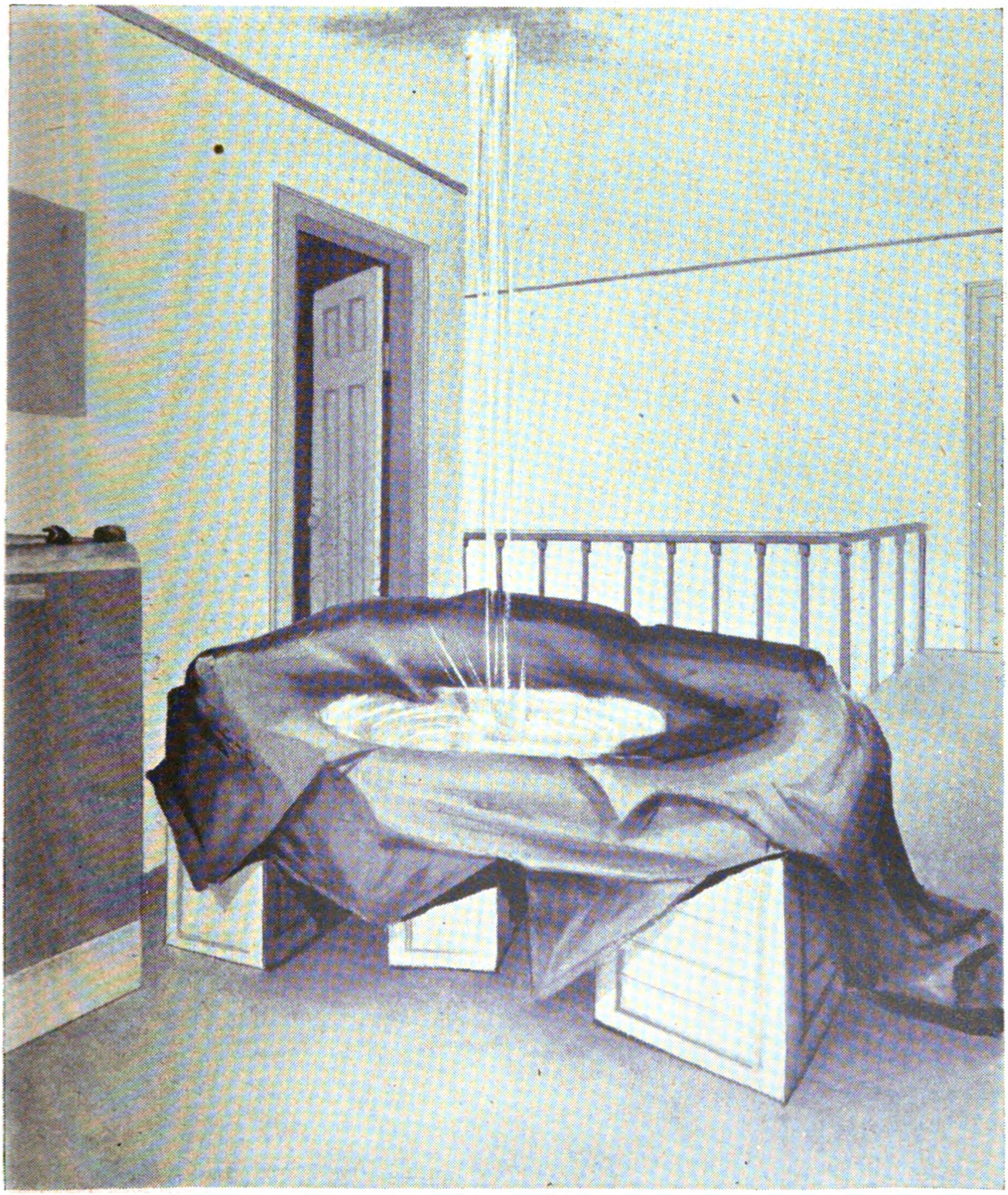


Figure 46. Catch basin.

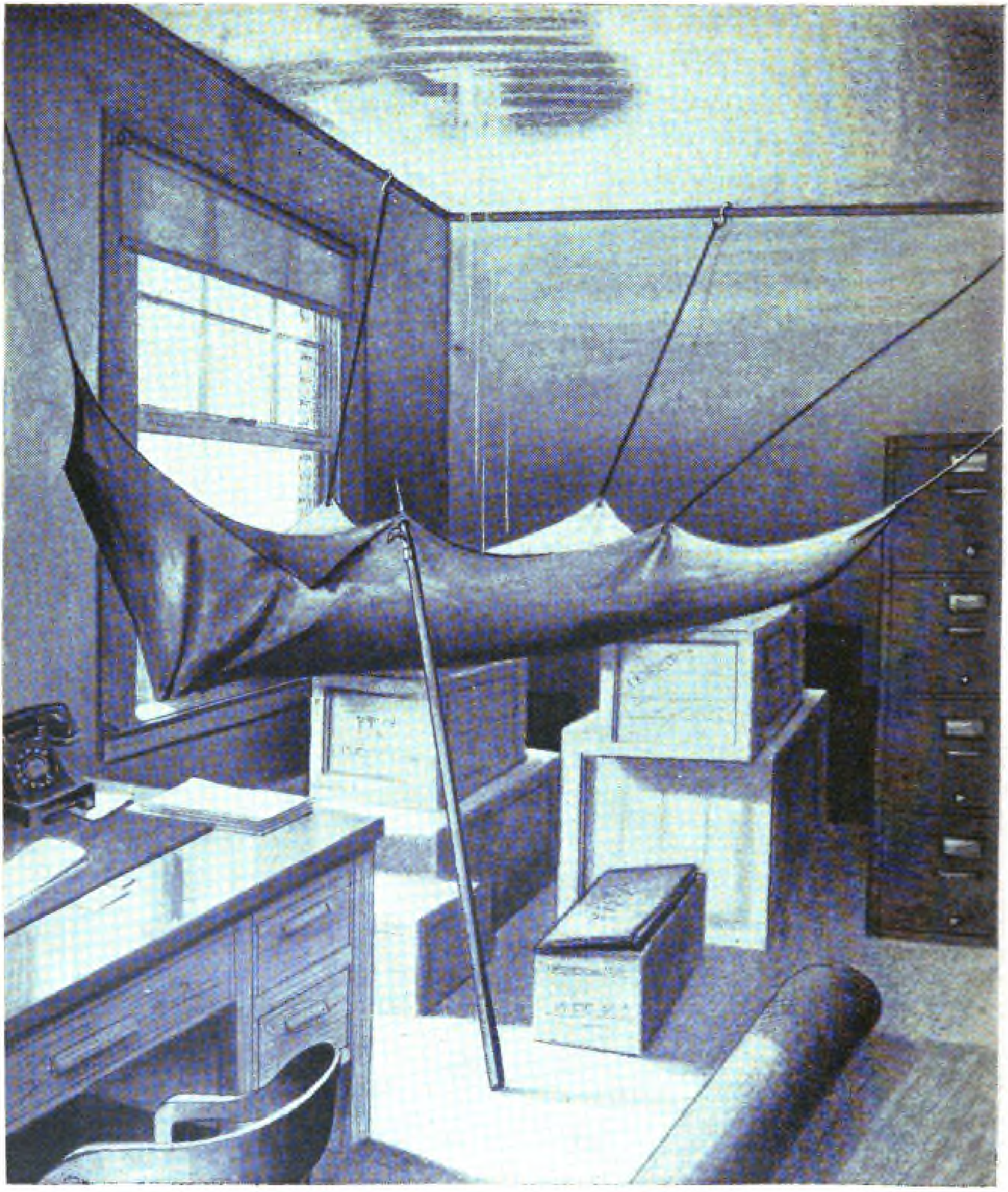


Figure 47. Window drain chute.

b. Window drain chutes (fig. 47). A chute to direct water out a window is constructed from a tarpaulin supported by S-hooks, cord, or pike poles. The supports are so arranged that water will run down the canvas toward the window. The S-hooks can be improvised from heavy wire, welding rod, or 3/16-inch cold rolled steel rod. Cut rods into 8-inch lengths, sharpen the ends, and bend into an "S" shape.

c. Stairway drains. Water is directed to lower floors or out of the building by stairway drains. When necessary to protect walks along the stairway, two tarpaulins are used. The first is spread from the bottom by a one-man throw, and the second is similarly spread from the top so as to overlap the lower one. The edges are fastened to or

thrown over the handrails. An alternate method is like that described above except that the edges of the tarpaulin are rolled inward to form curbs on each side of the stairway.

SECTION VI
ELECTRICAL FIRES

96. GENERAL. Correctly used, electricity provides safe illumination, power, and heating. However, when used incorrectly, it causes fires and casualties. Fires are caused through arcing, sparking, or overheating, and casualties through burns, shock, or falls as a result of shock.

97. CAUSES OF ELECTRICAL FIRES. a. Arc. When a loaded electric circuit is broken, an arc is produced, the intensity of which depends upon the current and voltage of the circuit. Since the temperature of an electric arc is high, nearby combustible material is usually ignited.

b. Sparks. An electric arc usually fuses the metal of the conductor in addition to igniting nearby combustible material. Sparks thrown out from the hot metal and burning material may set fire to other combustible material.

c. Overheating. Under ordinary circumstances the heating of conductors used to carry current is negligible. However, when a conductor is overloaded, not only is excess heat generated, but also the insulation of the conductor deteriorates, thus creating a fire hazard.

98. PROTECTIVE DEVICES. To prevent overheating of conductors, a fuse or circuit breaker is installed in each circuit. Both devices open the circuit and stop the flow of any current which exceeds a predetermined limit.

a. Fuse. The fuse is the most common form of overcurrent protective device. It consists of a fusible metal element which, when heated by the current to a certain temperature, melts and opens the circuit.

b. Circuit breaker. The circuit breaker is a mechanical means of opening the circuit. It is actuated by an electromagnetic device which trips the circuit-opening element when the current exceeds a predetermined limit.

99. INSPECTION. Hazards likely to be found in electrical devices are listed in the following:

a. Fuses and circuit breakers. (1) Dirty contacts at fuse terminals, resulting in local overheating and needless blowing of fuses, which often prompts the insertion of larger fuses.

(2) Fuses of too large capacity, or circuit breakers with too high a setting.
(3) Blown plug fuses in which pennies or other blocking have been inserted.
(4) Blown cartridge fuses in which nails, wires, or other metals have been inserted.
(5) Fuses or circuit breakers in poor mechanical condition.
(6) Fuses, without enclosures, near combustible material.
(7) Doors or covers of fuse cabinets off or opened.

b. Wiring. (1) Corrosion of metal covering or enclosures of conductors.
(2) Covers removed from outlet or junction boxes.
(3) Conductors of "open wiring" systems separated from their supports or in contact with each other or with pipes, woodwork, or other conducting or combustible material.
(4) Conductor insulation deteriorated from age or mechanical injury, or from exposure to heat, moisture, or vapors.
(5) Conductors overloaded.
(6) Joints not properly soldered and taped.
(7) Failure to replace temporary wiring.
(8) Absence of rigid conduit with vaporproof fixtures when gasoline vapors are present.

c. Switches. (1) Arcing produced when the switching device is operated. Many switches are either designed or enclosed to prevent arcing.
(2) Pitting or burning of contacts at points where circuit is made or broken.
(3) Overheating from poor contact or overload.
(4) Poor mechanical condition resulting from use or abuse.
(5) Corrosion.
(6) Inclosures missing or ineffective.

d. Switchboards. Switchboards vary in size from the massive installations sometimes used in generating stations or for service boards, to the small ones with generators of small capacity. They are generally of the open type, but are sometimes wholly or partially inclosed. Hazards are—
(1) Those common to switches, overcurrent protective devices, and a large number of conductors.
(2) Location near unprotected combustible material.
(3) Wood floors or combustible ceiling close above a switchboard not having special protection.

e. Lamps. (1) Chief hazard of incandescent lamps is of heating and igniting combustible material in contact with them. Also where there are flammable vapors, gases, or dust, breakage of lamps is a hazard.

(2) Certain gas-filled lamps in common use become hotter than incandescent lamps, the gas conducting heat from filament to glass bulb. If lamps are surrounded by or laid on combustible material such as paper or cloth, cooling by heat radiation is reduced and material may ignite.

(3) Neon lamps operate from transformers with potentials as high as 15,000 volts. Unless properly installed and maintained, this type of lamp presents a distinct hazard from arcing on high voltage side.

f. Portable lamps. (1) Use of unapproved, defective cord, or cord not suited to the purpose.

(2) Failure to provide means of safe disconnection in case of unexpected strain on cord.

(3) Failure to use lamp guards, or use of frail or ineffective guards.

g. Sockets. (1) Parts not mechanically fastened together.

(2) Overloading; for example, a 500-watt appliance connected to a socket with a 250-watt capacity.

h. Flexible cords. (1) Defective insulation.

(2) Cord tied or draped over pipes, nails, or other supports.

(3) Cord on pendant lamps long enough to allow lamp to be struck by traffic passing below.

(4) Cord used for fixed wiring, spliced and tacked, stapled, or otherwise fastened to walls or woodwork.

i. Motors. (1) Short-circuited or grounded electrical parts.

(2) Arcing and sparking at brushes.

(3) Lint and dust in motors.

(4) Overloading.

j. Generators. Electric generators, dynamos, rotary converters, and motor generator sets present hazards similar to those of motors. Generally they are in separate rooms or sections of the building and under supervision. Any combustible material near them should be protected. Overcurrent protection is essential to safe operation.

k. Transformers. Hazard is that high potentials generally used will ignite combustible oil in usual type of transformers with high-voltage primaries. As a general rule, power transformers should be located in locked fire-resistant vaults.

100. EXTINGUISHING ELECTRIC FIRES. In fighting fires in electrical equipment, both damage to the equipment and danger to the operator must be considered. The best practice is to shut off the current first; then, if the fire continues, to use the extinguishing means most suitable for the condition.

a. Small fires. For small fires in electrical equipment, carbon tetrachloride or carbon dioxide extinguishers are the most satisfactory. Their extinguishing agents do no damage to equipment, and since they

are nonconductors of electricity, may be used before the current is cut off.

b. Use of water. If the fire has gained headway and is quite intense, it may be necessary to apply water. Before water is used, however, the electric current is cut off; otherwise, additional damage may result and the operator may receive electric shock. A small fog nozzle is used to prevent unnecessary water damage to nearby equipment. When fighting the fire with solid streams of water, safe distances must be maintained to prevent electricity from traveling through the water to the operator. Streams from large nozzles conduct more current than those from small ones because the conducting stream of water is larger. They also conduct it for greater distances from the nozzle because the solid stream carries farther before it breaks. The following table shows the approximate safe distances under average conditions.

Voltage	Minimum safe distance using 1⅛-inch nozzle (feet)	
	Fresh water	Salt water*
1,100	6	25
2,200	11	25
3,300	15	30
5,500	18	30
6,600	19	30
11,000	20	30
22,000	25	30
33,000	30	35

* Salt water is the better conductor of electricity and should be used only under high pressure and at a distance which will give a broken stream.

c. When current cannot be cut off at a switch, cut the wires leading from the source of supply to the building. Cut them at the loop entering the building, or at the pole, one wire at a time. Leave one longer than the other, and then wind the loose ends around the pole one above the other.

d. When cutting live wires—all wires must be considered as live ones—use insulated wire cutters. The operator should stand on a dry ladder or other nonconducting dry object. To prevent shock and injury, when using the wire cutter he always should wear rubber gloves protected with leather ones. Except in emergencies, only persons especially trained and equipped with properly insulated cutting tools should attempt to cut live wires or otherwise touch unfamiliar electrical equipment. Engineer utilities detachments, or persons responsible for maintenance of electrical equipment, are organized, trained, and equipped for such jobs. Arrangements should be made in advance for emergency crews to report to the fire section at hazardous locations.

e. To eliminate hazards and to prevent fires resulting from careless operation, the fire fighters should make thorough and frequent inspections of all electrical equipment.

SECTION VII

STANDARD FIRE-DEPARTMENT HAND SIGNALS

101. GENERAL. **a.** The difficulties experienced in getting lines into place after they are charged, in kinking broken lines, and in extending and reducing lines are well known in the fire service. No matter how quickly a line is placed in position for service, water is delayed if messengers must be sent to the pump operator. If the pump operator turns the water into the line before it is ready for action, delay occurs in placing the line properly. The voice is not a dependable method of communicating with operator because of the noise of the motor and other distractions always present during a fire.

b. The standard signals may be transmitted by hand by day and by lantern or flashlight by night. They cover most of the important orders usually transmitted from the officer in charge to the engine or pump operator. Pump operators constantly watch for signals and acknowledge all signals by repeating them. If more than one line is in use from a pumper, it often is necessary to designate which line the signal is intended to cover.

c. Standard signals are understood easily, since in most cases they suggest the action desired. Careless signals are likely to be misunderstood and are worse than no signals at all. It may be desirable to develop additional signals to fill special needs. They should not be the same as the standard signals and should be understood readily by all concerned.

d. Commonly used hand signals are:

(1) CHARGE THE LINE. During the *day* this signal is given by raising both arms vertically from the shoulders, palms to the front, and holding them stationary until the signal is acknowledged (fig. 48). At *night* it is given by holding a flashlight or lantern in one hand and raising the arm vertically above the head. The beam is directed toward the pump operator and the light swung horizontally above the head (fig. 48).

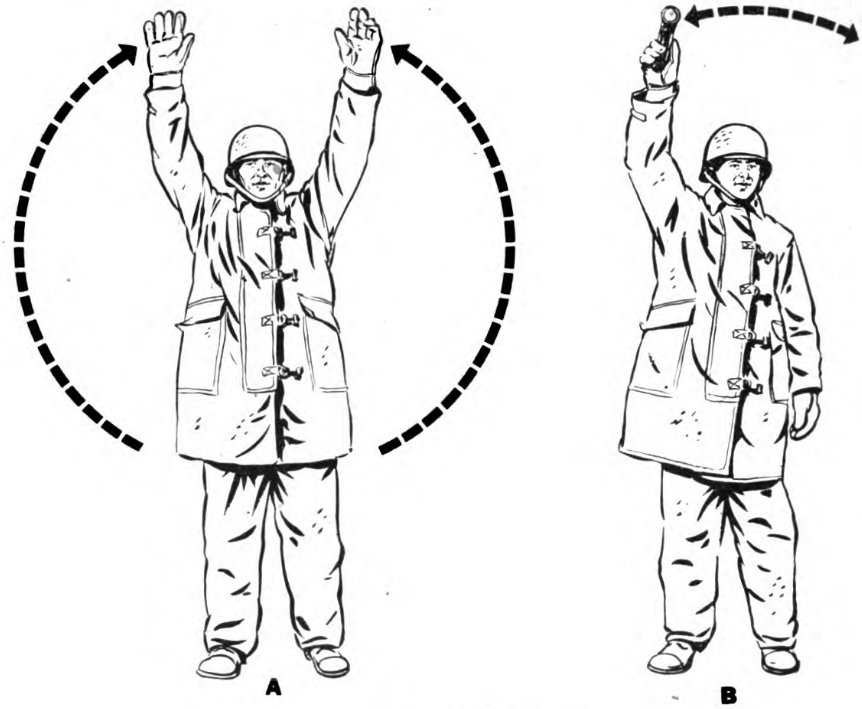


Figure 48. Signal to charge line.

(2) SHUT OFF WATER IN THE LINE. This signal is for a temporary shut-down to allow line repairs or changes. On receiving it, the operator closes the discharge valve but continues to pump and holds himself ready to reopen the valve at the proper signal. During

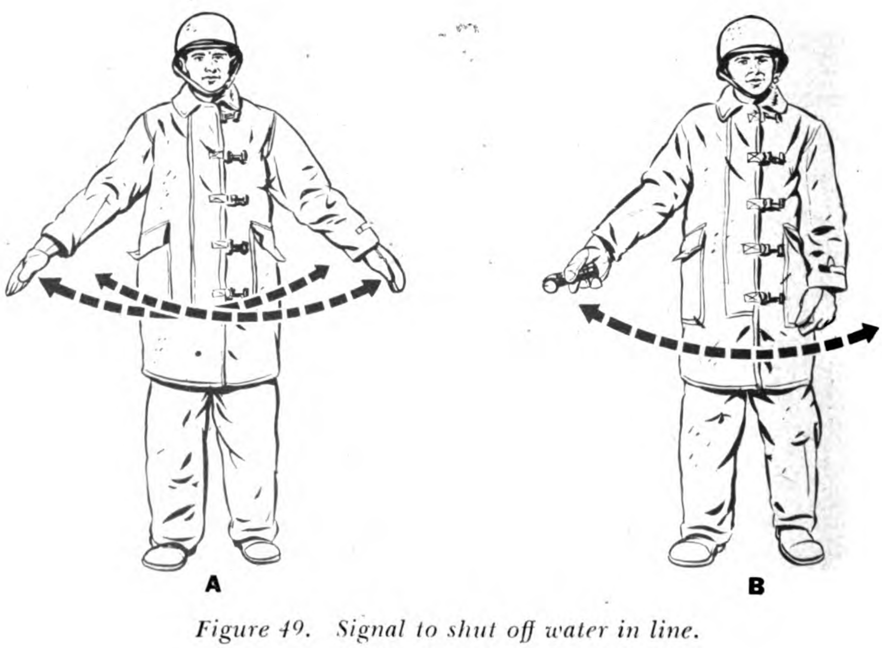


Figure 49. Signal to shut off water in line.

the day, the signal to shut off the water is given by extending both arms downward at an angle of 45°, crossing them in front of the body, and swinging them back and forth (fig. 49). At *night* it is given by extending one arm downward at an angle of 45°, directing the beam of a flashlight or lantern toward the pump operator, and swinging the arm back and forth in front of the body (fig. 49).

(3) CEASE OPERATIONS. This signal means that the job is finished. On receiving it, the operator disengages the pump, disconnects all lines, and picks up his equipment. During the *day* this signal is given by describing a circle in front of the body with one arm extended, bending the knees slightly (fig. 50). At *night* it is given by holding a light in one hand and, with the arm extended, describing a circle in front of the body (fig. 50).

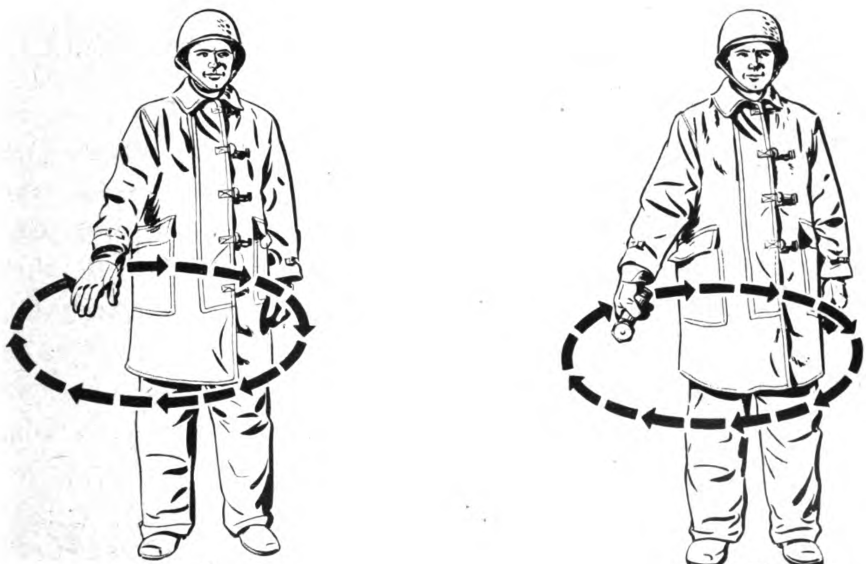


Figure 50. Signal to cease operations.

(4) INCREASE PRESSURE. This signal is used to ask an increase in pump pressure of 20 pounds per square inch. If a larger increase is desired, the signal is repeated as many times as necessary. During the *day* this signal is given by extending the arms horizontally from the shoulders and raising them to a 45° angle, palms up. The signal is repeated until answered (fig. 51). At *night* it is given by extending one arm horizontally from the shoulder, holding a light in the hand so as to direct a beam toward the pump operator, then raising the arm to a 45° angle. The signal is repeated until answered (fig. 51).

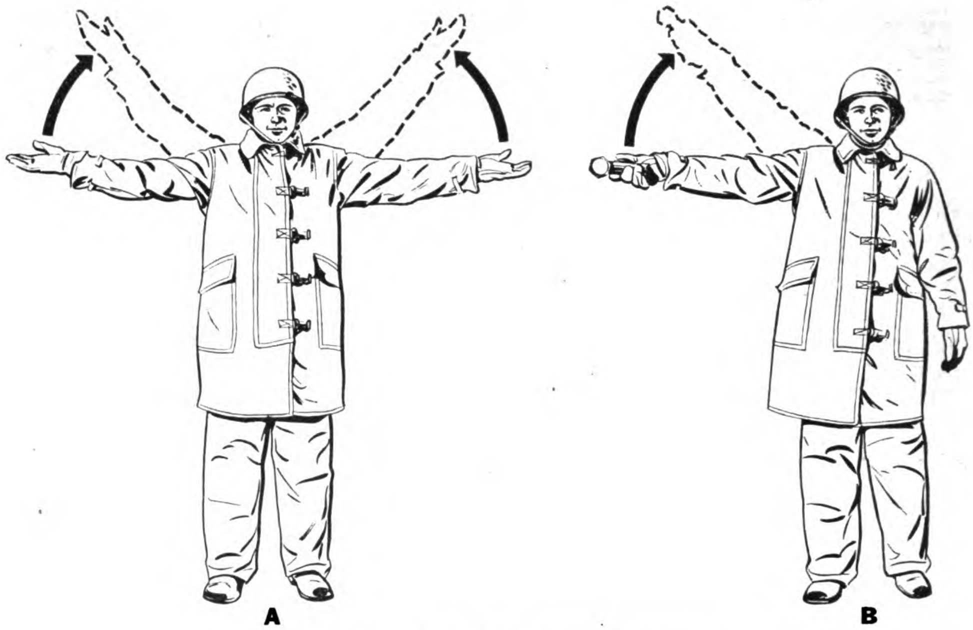


Figure 51. Signal to increase pressure.

(5) DECREASE PRESSURE. Each signal indicates a decrease in pump pressure of 20 pounds per square inch. During the *day* it is given by extending the arms horizontally from the shoulders and lowering them to a 45° angle, palms down. The signal is repeated until answered (fig. 52). At *night* it is given by extending one arm horizontally from the shoulder, holding a light in the hand so as to direct the beam toward the pump operator, then lowering the arm to a 45° angle. The signal is repeated until answered (fig. 52).

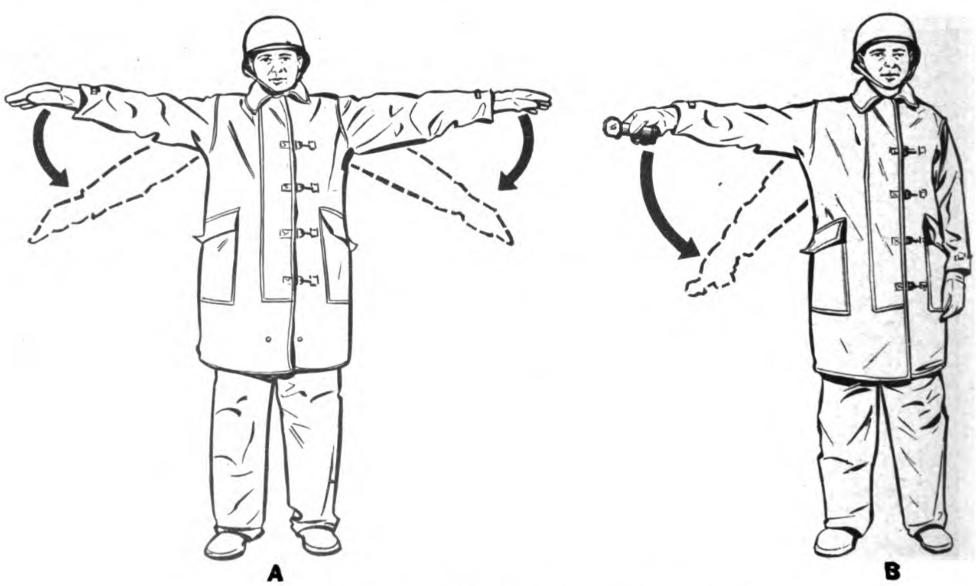


Figure 52. Signal to decrease pressure.

SECTION VIII
PETROLEUM FIRE CONTROL

102. PETROLEUM. Petroleum is usually produced, transported, and stored in liquid form. Its products may be liquids, solids, or gases; but most of them are liquids.

a. Volatility. All liquids and solids must be changed to a gas or vaporized to burn. Volatility is the term used to indicate the tendency of a liquid or a solid to vaporize and is expressed as vapor pressure.

b. Vapor pressure. Vapor pressure is measured in pounds per square inch. It increases with rising temperature. When a substance has such a temperature that the vapor pressure on its surface is equal to atmospheric pressure, the substance is at its boiling point.

c. Flash point. Volatility or vapor pressure must be considered when determining the cause or the possible spread of a fire. If the vapor pressure of petroleum or a byproduct is approximately 2½ ounces per square inch, enough vapor is formed to create a combustible vapor mixture above the surface of the substance. The temperature required to produce this pressure in a given substance is its flash point.

103. COOLING LIQUIDS AND SOLIDS. Some grades of crude petroleum and petroleum products can be cooled below their flash points by a cooling agent of a lower temperature applied in sufficient quantities. It is ordinary procedure to wet the surface of a burning solid with water to reduce the vapor pressure, but it is difficult to apply water to a burning surface of a liquid.

a. High-velocity stream. With viscous oils, a high-velocity stream is forced below the surface to cause convection currents. The cooler liquid at the bottom contacts the hot surface liquid and absorbs its heat faster than the burning vapors above can heat the surface. If the temperature is above the flash point only at the surface, small containers of some grades of burning viscous petroleum products may be cooled sufficiently to reduce the vapor pressure below 2 ounces per square inch by stirring with a stick or paddle. However, high-velocity stream applied to liquid petroleum causes excessive atomization and hence increases the vapor, for as more of the surface of the liquid is exposed, the small particles quickly change to gas.

b. Low-velocity stream. A high-pressure, low-velocity water-fog stream is used to extinguish petroleum fires. The minute particles of water do not agitate the liquid or cause atomization, but quickly change to steam as the heat from the liquid surface is absorbed. If the liquid

(which is above the flash point) is heated only at or near the surface, the fire quickly is extinguished.

104. HEAT WAVE. As they burn at the surface, some oils of the heavy viscous type produce an ash which settles down into the oil, heating it. The result is an increased mass of extremely hot oil between the burning surface and a very sharply defined "heat wave front" dividing the hot oil from the cold oil. If water is applied continuously to this mass of hot oil, it froths or expands tenfold, 1 foot of hot oil forming 10 feet of froth. Therefore unless there is considerable space between the liquid level and the top rim of the tank, the water is applied for only a few seconds at a time. Slop-overs should be avoided. However if the tank does slop over, the froth is easily extinguished with water streams.

TABLE VII. *Approximate heat wave and burning rates*

Kind of oil	Type of oil	Heat-wave rate (inches per hour)	Burning rate (inches per hour)
Crude oil	Viscous, about 25° gravity.	15 to 50	4 to 18
Crude oil	Viscous, below 25° gravity.	3 to 50	3 to 5
Fuel oil	Viscous, below 25° gravity.	3 to 50	3 to 5
Light distillate	Nonviscous.	0	5 to 8
Kerosene	Nonviscous.	0	5 to 8
Gasoline	Nonviscous.	0	6 to 12
Natural gasoline	Nonviscous.	0	15 to 25

a. Methods for determining heat wave depth. The amount of heat wave can be determined by observing the liquid level and the reaction to the application of a small amount of water below the surface. This water changes to steam if the oil is hot. For positive proof, a stripe of indicator paint is painted at several points on the windward side of the tank. This paint is composed of a mixture of cuprous-mercuric iodide and diatomaceous earth, with varnish as a base. The chemical changes from a bright red to a deep maroon when it rises to 150° F., or above.

b. Treatment. Oils subject to heat wave should be treated with water immediately. If the heat wave extends to the bottom of the tank,

it contacts water, as this type of oil nearly always contains water, which settles to the bottom. When the heat wave strikes the water, the tank boils over and spreads the fire. If fire control is properly supervised, there will be no such boiling.

105. COOLING THE HEAT WAVE. If the temperature of the burning viscous liquid petroleum or petroleum product is above the flash point throughout the entire mass, a high-pressure, low-velocity water fog stream may be used if applied intermittently. The first application should be for only a few seconds. When it is made, the minute water particles on the surface change rapidly to steam causing agitation of the surface liquid, thereby releasing more vapor to the flames above. As a result, the burning increases, the flame becomes brighter in color, and the smoke diminishes. This condition lasts for a few seconds. After the water fog stream has been removed, the burning action soon recedes to burning quietly over the entire surface or only a portion of it, depending upon the viscosity of the liquid.

a. Forming a froth blanket. Heated viscous oils, such as crude oil, fuel oil, asphalt, and lubricating oils, form a froth when the water particles changing to steam agitate the oil and are encased by it, replacing the portions of the oil which otherwise would have been changed to inflammable vapor. The depth of this froth blanket depends upon the viscosity of the oil, the amount of water used, and the distribution of the water particles over the liquid surface. The froth formed in an oil in this manner breaks down rapidly. Hence the entire surface should be covered with water fog to prevent the flames from one part of the fire from reigniting the oil in another part as soon as the froth is broken down. This usually requires several streams and a well-coordinated organization of hosemen, for the water from all streams must be simultaneously directed on and off the oil at a given signal. After each application of water fog the time of froth breakdown increases and more water-fog is required to produce the froth. The person directing the water-fog streams always should use the intensity of the fire as the indicator in determining the amount of water to be applied.

b. Large-tank application. A burning tank over 40 feet in diameter in which heat waves have developed may be difficult to cover with water-fog streams because of the streams' limited range. Under these circumstances it may be necessary to use high-velocity streams. They should be directed high so that the surface of the oil will not be disturbed any more than necessary. Using these streams, it will probably not be possible to extinguish the fire by the formation of froth, but it will be possible to reduce the heat wave to a minimum so that foam can be used to extinguish it.

106. FOAM APPLICATION. Foam is a viscous emulsion prepared by mixing glucose or other sticky material with water, the water to form approximately 88 percent of the total mixture. If foam is applied to a hot oil surface, the results are the same as when water is used in a high-velocity stream. It is not practical to use large volumes of foam in a high-pressure, low-velocity stream. Furthermore, water serves the purpose of precooling more efficiently.

a. Foam extinguishment principle. Foam controls fire in liquid petroleum and petroleum products by forming an impervious blanket which confines the vapors within the liquid. The weight and viscosity of the foam blanket must be sufficient to maintain the vapor pressure below 2 ounces per square inch. A blanket cannot be formed properly on a hot viscous oil surface, for the steam formed by the expansion of the water in the foam breaks up the blanket allowing the development of vapors.

b. Foam extinguishment limitations. Burning nonviscous petroleum products, with a vapor pressure equal to or less than that of gasoline at normal temperatures, are controlled quickly if the foam is applied properly. However, the vapor pressure of natural gasoline at normal temperature is too high to permit the proper formation of a foam blanket.

107. NONVISCOUS PRODUCTS OF PETROLEUM. a. General. Burning nonviscous products of petroleum present a different problem. Some of these products, such as kerosene and distillate, have pressures less than 2 ounces per square inch at normal temperatures and may be cooled below their flash point with water fog.

b. Gasoline vapor pressure. Gasoline has a flash point of 0°F., or less. Obviously, therefore, it cannot be extinguished by cooling the liquid. At normal temperatures its vapor pressure may be several pounds per square inch. It begins to boil at about 100° F.

108. EXPLOSIVE MIXTURES. a. Petroleum vapors cannot be burned except in the presence of oxygen, usually supplied by the air. As vapors are given off at the surface of a liquid, they diffuse and mix with the air. The rate of this diffusion is fairly rapid; the mixing may be accelerated by convection currents caused by temperature differences. Even though there is a mixture of vapor and air in the vapor space above the liquid, it cannot be ignited or burned unless the volume of the vapor is within certain limiting percentages of the total mixture.

b. For gasoline vapors these limiting percentages are approximately 1 percent and 6 percent by volume. Mixtures containing less than 1 percent are too "lean" to burn at atmospheric pressure; those containing more than 6 percent are too "rich" to burn except upon contact or mixture with additional air.

c. At atmospheric temperatures and pressures, air-vapor mixtures above low-flash point liquids usually are too "rich" to burn. Vapor mixtures over liquids with high flash points usually are too "lean" to burn. Vapor mixtures over liquids with flash points approximating prevailing atmospheric temperatures are likely to be within the combustible limits.

d. While the combustible or explosive limits for gasoline vapor in air are about 1 percent and 6 percent by volume, other petroleum vapors may have lower or higher limits, depending upon their composition. Vapors from hot heavy oils may burn at as low a concentration as 0.4 percent; on the other hand, vapors containing 6 or 9 percent of propane, butane, or pentane, may burn.

e. For natural gas the combustible limits are approximately 5 percent and 15 percent. For hydrogen sulfide, which is found in certain crude oils, those limits are 4.3 percent and 46 percent.

109. DILUTION OF VAPORS. **a.** To extinguish burning gasoline it is necessary to reduce the percentage of vapor produced below 1 percent by dilution, to blanket the surface to reduce the production of vapors below 1 percent, or to dilute the oxygen content of the vapor-air mixture.

b. It is possible to dilute both the vapors and the oxygen with live steam, carbon dioxide, and other noncombustible gases. However, except for small fires, the quantity required, the difficulty of application and other limitations have made their use impractical. Low-velocity water fog applied in such a manner as to fill the vapor space with minute particles of water, equally distributed in a homogeneous mass, absorbs the heat from the burning vapors and in so doing is changed to steam. The rapid expansion of each water particle dilutes the vapor and oxygen content enough to extinguish fires in tanks up to 20 feet in diameter. The intensity of fires in larger tanks can be reduced in this manner to make possible an easier extinguishment by the application of foam which will blanket the surface and reduce the production of vapors to less than 1 percent.

c. The temperature of the vapor-air mixture is above 170°F. when the water particles of the low-velocity water fog change to steam. If too much water fog is applied, the temperature may drop too quickly to trap steam over the entire surface, leaving only the water particles to act as the dilution agent. This results in a flicker of flame which may be extinguished by adding more water fog, or by allowing the tank to heat again and repeating the operation using less water.

110. VENT FIRES. Oil stored in tanks and topped with vapors in explosive mixtures may ignite and create a terrific explosion. Generally,

tanks are constructed of iron or steel, though some have wooden tops or covers. If the tops are of iron or steel, the construction is much weaker than that of the lower plates comprising the tanks. This is to allow the escape of any unusual force generated on the interior of the tank by an explosion, and thereby prevent any rupture which would allow the burning oil to flow out of the tank sides.

a. Vent construction. The tops of some oil tanks are constructed with hinged doors, shutters, or explosion hatches which open to liberate any unusual interior pressure and which, after the pressure has been liberated and dissipated, fall back into their original closed position, and extinguish the fire in the tank by cutting off the air necessary for combustion. For oil field storage, flange-welded tanks have been developed which allow for contraction and expansion, thus minimizing the possibility of the joints parting. Repairs can be made easily from the outside of the tank with simple caulking tools.

b. Flame arrestors. Flame arrestors are devices which, when installed in pipe lines, permit inflammable and explosive vapors or gases to pass freely but which, when a fire occurs, prevent its passage through the pipe. With large oil tanks containing inflammable liquids and gases, some means of ventilation through pipes (called vents) to the outside air is required. If the gas becomes ignited outside the tanks, the flame may pass back into the tank, causing an explosion if the proper air-vapor mixture is contained therein. The proper installation of an arrestor in the vent line tends to stop the passage of flame. However, it is difficult to construct a flame arrestor which will remain efficient and yet not interfere with ordinary operations of the line.

c. Vent limitations. If a tank is in an external fire and the fire becomes intense, hardly any vent of reasonable capacity will take care of the generation of gases inside the tank, for vaporization is extremely rapid as the heat intensifies. There is also the danger that the vent will clog, or the seat warp, so as to allow the pressure in the tank to rise sufficiently to cause a rupture of the tank shell and consequent spilling of the hot oil on the surrounding area.

d. Flame travel. (1) The important thing to know about vent fires is the danger that the flame will flash back into the container and cause a violent explosion. Of course, this depends on the percentage of petroleum vapor in the air mixture within the container. If there is more than 6 percent oil vapor in the mixture, there will not be enough oxygen in the inclosed space to support combustion inside, but the stream issuing from the vent will mix with oxygen from the air and burn as a torch at the vent as long as it flows.

(2) Even with an explosive mixture within the tank, the flame may not flash back through the vent and cause an explosion. Flame advances through an explosive mixture at a rate determined experi-

mentally to be something less than 15 feet per second. Hence, even if it is within the explosive limits, when a vapor-air mixture issuing from a container at a rate in excess of 15 feet per second is ignited from the outside, the flame will not travel back into the container as long as the rate of flow is undiminished.

e. Flame character. The explosibility of a vapor-air mixture burning at an outlet can be estimated from the character of the flame; the flame from a rich mixture is yellow, smoky, and luminous, whereas the flame from an explosive mixture is blue, nonluminous and contains little smoke. It is safe to assume that a mixture is nonexplosive if it is burning at an opening larger than 3 inches in diameter, unprotected by breather valve or other flame arrestor. Unless air is sucked into the tank through some other opening, there is no danger of an explosion. If the air-vapor mixture burns with a bluish, nonluminous flame, the mixture must be enriched to prevent an explosion. This is done by increasing the volume of outflow by pumping oil or gas into the tank, or by allowing the shell of the tank to become heated. When the flame becomes smoky, yellow, and luminous, the extinguishing procedure may be started.

f. Extinguishing methods. (1) Vapor fires are best extinguished by cutting off the supply of fuel or by shutting off the air supply from the vapor. If the vapor-air mixture is within the explosive limits, there is some danger in attempting to shut off the fuel supply because the decreased velocity of outflow may allow the flame to flash back into the container and cause an explosion. However, this is not likely, for unless the velocity is high, or a breather valve or flame arrestor is provided, if the mixture is explosive, it flashes back into the container immediately upon ignition.

(2) With rich vapor burning at a tank vent or other opening, the supply of fuel can be stopped by shutting off incoming lines and extinguishing outside fires heating the tank. Any method of mechanically shutting off the flow of vapor is effective in extinguishing fires of this character. The opening may be closed by a hatch cover or a wet blanket; or a water stream may be used temporarily to force back the vapor stream. If the fire is small, an inert gas, steam, carbon tetrachloride, or carbon dioxide can be used as a smothering agent; but usually it is more practical to extinguish a small fire of this kind by covering it with a blanket or any other suitable available material. However, if the vapor is flowing out under much pressure, such means as blankets may not be enough to shut off the flow.

111. BUTANE STORAGE AND HANDLING. *Butane* is a petroleum gas which is transported and stored as a liquid under pressure in steel pressure vessels. *Propane* is a similar but lighter petroleum gas. The

principal difference between the two is that propane is more volatile and requires more pressure to keep it in the liquid form. Commercial butane nearly always contains some propane to give it volatility. The pressure required to liquefy any given mixture of butane and propane probably will never exceed 200 pounds per square inch. Exact values depend upon the respective percentages of the two products in the mixture. Commercial butane and propane and their various mixtures are known in the oil trade as liquefied petroleum gases. From the standpoint of fire and fire control there is little difference between butane and propane and their various mixtures. Butane is stored in small containers of approximately 60-gallon capacity and in underground and above-ground tanks in camp installations as a substitute for natural or manufactured gas for heating and cooking. Also, it may be stored at post service stations, usually in underground, but sometimes in above-ground tanks, for dispensing through high-pressure hose into fuel tanks of trucks in which it is used as a substitute for gasoline as motor fuel. It is transported in tank trucks from which it is delivered to storage tanks or in tanks of less than tank-truck size, known as skid tanks, which are delivered full in exchange for empty ones.

a. Safety devices. (1) The pressure in any closed tank increases when it is heated. In tanks filled with butane, the pressure rises rapidly with the temperature. All small tanks of the portable type are equipped with one of two kinds of pressure safety devices:

(a) Fusible plugs that melt when a temperature of 200° F. is reached.

(b) Spring-loaded relief valves which open when the pressure exceeds a predetermined safety limit.

(2) Larger tanks, whether portable or stationary, almost always are equipped with the spring-loaded valve. When the tank is right side up, in the normal operating position, the relief valve is on top of the tank, hence only vapor comes from it when the tank is overheated. If, however, through accident, the tank is rolled over, the relief valve is below the liquid level and only liquid is released to relieve the tank pressure. With the release of liquid the fire hazard is increased because, if ignited, the flames from the issuing liquid stream is almost always directed against the shell of the tank, further increasing its temperature. This is exceedingly dangerous, and if allowed to continue almost invariably results in the bursting of the tank with an ensuing large flash of fire.

(3) Tanks used for the storage and transportation of butane are built for from 100 to 300 pounds pressure per square inch, depending upon the products carried. Hence they will stand more mechanical abuse than will the tank of a gasoline truck or the fuel tank of an automobile or other vehicle.

b. Comparison with natural (domestic) gas. Natural gas is lighter than air. It rises and disperses readily. Butane vapor is nearly twice as heavy as air. When first released, as a result of automatic refrigeration, it is even heavier. It disperses slowly and may run along the ground, collecting in low spots such as pits and basements some distance from the source of leakage. Commercial butane is odorized to make it smell like natural gas, but a vapor indicator is the only sure test for its presence.

c. Butane fire control. (1) A fire section may be called to a butane fed fire either before or after ignition of the butane. In either event primary consideration must be given to the amount of unburned butane vapor existing or permitted to accumulate in the area of exposure.

(2) Each liquid gallon of butane will produce about 35 cubic feet of butane vapor. As the liquid is released at atmospheric pressure, it vaporizes rapidly and freezes so as to appear in the air as a whitish cloud. In time the whitish appearance may leave it, the vapor then becoming invisible. A spill of 100 liquid gallons will give off enough vapor to cover an area 65 feet square, 1 foot deep. Vapor from 1,000 gallons will cover an area 190 feet square; that from 10,000 gallons, an area 600 feet square. Sometimes, especially in congested areas, the vapor may build up and stand as a mound-like mass, or may string out as a ribbon. At any point within such a vapor cloud the mixture is nearly always too rich to burn. However, that on the outer edges of the cloud is always in the explosive range. Ignition of any part of the cloud results in quick combustion throughout the entire mass.

(3) Combustion is accompanied by liberation of great heat and a strong outward push which may be destructive to frame structures, even though they do not lie directly in the vapor cloud. The heat generated may be sufficient to kindle paint and other light combustibles as far as 100 feet or more from the outer edges of the burning cloud. A human being or domestic animal within the vapor cloud or directly exposed to it at the time of ignition has little chance to survive the great heat and the destructive force of the explosion. Even though the temperature required to ignite butane vapor may be as low as 800° F., it is not set off by a steam radiator or a soldering iron. However, other heat sources must be considered dangerous, such as ignition and exhaust systems of any motor vehicle, open electrical devices, glowing or smoldering substances, and open flames.

d. Recommended procedure before ignition. (1) Approach the location from the windward side. If this is not possible, take a protected position so that vapor being moved along by the wind will be blown *by* your position but not *through* it. Proceed with the following in the order stated:

(a) Order all persons out of area immediately.

(b) Order them to leave on foot, not by motor vehicle if the vehicle must be started.

(c) Close down all sources of ignition which lie within probable path of vapor drift.

(d) Detail men and equipment to fight the fire and to protect exposed property in event vapor ignites.

(2) Never for any reason detail men to enter a vapor cloud or any area directly exposed to it, if large spills are involved and large amounts of vapor are already present. If the spill is small or a strong breeze is blowing the vapor away from the point of leakage, men may be sent in to close valves, but only after judgment indicates that suitable protection can be provided by fog nozzle hose streams. Any such undertaking requires utmost caution.

e. Recommended procedure after ignition. Take up a protected position on the windward side of the fire, or to one side of the probable path of any unburned vapor. Proceed with the following in the order stated:

(1) Order all persons out of area and hold them behind a line at least 100 feet from the burning or exposed tanks.

(2) Work in toward center of fire and try to bring source of burning butane into view. Keep fog lines on the tanks and on adjacent exposures, but *do not attempt totally to extinguish the fire at this stage, even though you find it easy to do so.* First, look at the tank to see if it is in an upright position. If it is horizontal, approach from the side, not from the end. Determine whether the relief valves are blowing vapor. If it is a tank truck, check to see if liquid is issuing from the discharge connection to which the hose is normally connected. If the equipment involved is part of a system other than a tank truck, determine what means, if any, are present for shutting off the fuel.

(3) If a shut-down seems possible, continue to play streams on tank, especially where flames touch upon it. Work in slowly, to see if the pressure in the tank is diminishing. This can be determined by noting the velocity with which vapor or liquid issues from the relief valves or vent openings.

(4) If pressure diminishes or remains constant, continue to work in toward the shut-off points, knocking down fire as much as possible, but being careful not to extinguish it. Then try to close the shut-offs, protecting the men with fog lines. If the pressure seems to increase in spite of your efforts, a tank burst is probable. Withdraw to a safe distance.

(5) If shut-off is not successful, *do not extinguish fire.* Instead, resume cooling operations and control the rate of burning until all butane fuel

has been consumed. If the shut-off is successful, knock down any remaining fire and check the tanks and equipment for small leaks.

112. SPECIAL PRECAUTIONS—ARMY AIR FORCES. Reference is made to detailed information with respect to flammable liquids, characteristics and methods of storage, handling, and fire protection methods contained in "U. S. Army Air Forces Air Transport Command Manual of Safe Operating Procedures for Handling Aviation Gasoline at Airports and For Fueling Planes," from the Engineer Advisory Committee on Oil Storage sponsored jointly by the War Department and the Navy Department, July, 1943, as published by AAF Air Transport Command. This reference material is also contained in Part 3, Chapter 8, "Fuel Systems and Gasoline Storage of the AAF Air Transport Command Supply and Service Manual 65–1."

SECTION IX
AIRPLANE CRASH OPERATIONS

113. KNOWLEDGE REQUIRED. a. General. The technique of airplane crash fire protection is relatively new and is still under development. Effective operation requires an intimate knowledge of all phases and parts of military aircraft, the tendency of fire in specific types of planes and under specific conditions as determined from actual experience, rapid thinking, good judgment, and positive decision as to the procedure to be followed. More than in any other type of fire protection the necessity is paramount for planning a complete course of action in advance and placing it in operation in the shortest possible time. The subject of airplane fire protection and crash fire fighting is too voluminous to incorporate in any general fire-fighting manual, and is made the subject of a separate and complete publication. (See TM 5–316.) In all airplane crashes the rescue of personnel is of first importance, fire fighting is secondary. Teamwork and speed are absolutely necessary: seconds lost may mean lives lost. Hence, fire-fighting personnel must have a thorough knowledge of the following phases of their work:

b. Truck and pump operation. (1) Pump instructions.
(2) Stretching of foam lines.
(3) Stretching of fog lines.
(4) Use of fire-fighting and crash tools.
(5) Operation of hand extinguishers.
(6) Methods of refilling tanks for continuous foam operations.

(7) Methods of refilling tanks for continuous fog operations.
(8) Servicing of crash trucks after use.

c. Aircraft identification. (1) Types of aircraft.
(2) Operating personnel and passenger capacity of aircraft.
(3) Location of personnel.
(4) Location and operation of gasoline shut-off valves.
(5) Location and operation of battery and ignition switches.
(6) Battery locations.
(7) Gasoline capacity.
(8) Number of tanks.
(9) Location of tanks.
(10) Location and operation of controls for fixed fire extinguishing systems.
(11) Amount and location of small ammunition, bombs, flares, and guns.

d. Forcible entry and rescue. (1) Location of emergency escape hatches.
(2) Means of opening escape hatches from outside.
(3) Location of fixed equipment that would impede forcible entry operations.
(4) How to cut safety belts and parachutes.
(5) How to remove jammed control stick.
(6) Where and how to cut cables of jammed controls.
(7) Use of crash tool kit.
(8) Use of asbestos suits.

e. Extinguishing methods. (1) Use of foam streams.
(2) Use of fog streams and applicators.
(3) Use of carbon dioxide.
(4) Use of the combination of any two of the above methods.
(5) Use of fog streams for rescue work.

f. Fire and safety precautions. (1) Truck approach must be from the windward side and at a safe distance.
(2) Place battery and ignition switches in "off" position.
(3) Disconnect batteries and tape terminals. *Always disconnect ground wire first.*
(4) Shut off all gasoline valves, plug leaks, and take care not to operate dump valve.
(5) Blanket leaking gasoline immediately with foam or sweep it away with high-pressure fog.
(6) Avoid passing in front of guns.
(7) Exercise care in working around aircraft loaded with bombs.
(8) Have gasoline removed from tanks before moving airplane, if tanks are in danger of rupturing.
(9) Allow no smoking within 200 feet of crashed aircraft.

(10) Do not remove any articles or equipment from airplane except batteries.

(11) Do not destroy or damage airplane any more than required by fire-fighting and rescue operations. Vital evidence necessary to determine cause of crash may be destroyed.

(12) In large movements of aircraft, station all available equipment along the runway.

g. Crash landings for which preparations can be made. (1) Determine type of airplane to crash.

(2) Assign definite duties and positions to crews.

(3) Station equipment for best advantage.

(4) Inspect crash area.

(5) Discuss pending crash with base operations officer. Find out reason for crash, what action may be expected of airplane, number and location of personnel, amount of gasoline remaining in airplane, and similar details.

(6) Move a reserve supply of foam and water near site.

h. Crash landings off the field for which preparations cannot be made.

(1) Study terrain of crash area by reference to map.

(2) Determine best route of access.

i. References and sources of information.

(1) Pilots' instruction manuals.

(2) Truck operating manuals.

(3) Pump operating manuals.

(4) Manufacturers' manuals.

(5) Repair and utility manual, file No. 0702.04/32.

(6) Personal inspection and study of aircraft by crews.

(7) Base operations officer.

(8) Base engineer officer.

(9) U. S. Army Air Force Transport Command Manual of Safe Procedures for Handling Aviation Gasoline at Airports and for Fueling Planes.

114. CRASH PERSONNEL PLACEMENT DUTIES. a. Personnel placement and duties for class 125 fire truck. (1) No. 1, the section chief, rides in the right front seat. Upon arrival at the crash, he makes a size-up and directs the section's operations.

(2) No. 2, the driver and pump operator, drives the truck and operates the pump. He watches closely all operations instruments and all working parts of the pump and engine. He is on the alert for hand signals from the chief or other designated person.

(3) No. 3, a nozzle man, rides on the right side of the rear platform. He takes the nozzle from the right side of the truck and advances to the crash. He follows the chief's orders.

(4) No. 4, a rescue and hose man, rides on the right center of the rear platform. He pays the hose out of the basket and then runs to the crash with the crash kit and asbestos suit. He follows the chief's orders for rescue and other work.

(5) No. 5, a nozzle man, rides on the left side of the rear platform. His duties are the same as those of No. 3.

(6) No. 6, rescue and hose man, rides on the left center of the rear platform. His duties are the same as those of No. 4.

b. Pump controls in cab of class 125 fire truck. (1) FOG OPERATIONS. Set the hand brake, idle the engine, and disengage the clutch. Keep the clutch disengaged until the road gear is locked in second gear and levers marked "truck drive" and "equipment drive" are pulled back. The transmission now is out of road gear and in pump gear; the pump is operating slowly. Dismount and go to the pump controls on the left side of the truck. Open the panel, the tank suction valve, and finally the discharge valves to the lines to be used. Accelerate the motor to the warning line on the speedometer in the cab and, at the same time, turn the churn valve clockwise until it is closed. Maintain a pressure of 750 pounds per square inch.

(2) FOAM OPERATIONS. When foam is desired, engage the pump as outlined above. Open the foam valve; this releases the 20 gallons of foam solution into the 300-gallon booster tank. Now slowly turn the churn valve clockwise until the gauge shows 260 pounds per square inch. Finally, open the discharge valves to the lines being used.

c. Pump controls outside cab of class 125 fire truck. (1) FOG OPERATIONS. Set the hand brake, step to the right side of the truck, open the panel and lift the level clutch to the upright position. Open the cab door and lock the road-gear lever in second gear. Now move the outside levers marked "truck drive" and "equipment drive" from the "road" to the "pump" positions. Accelerate the motor to a fast idle with the outside hand throttle, pull the intake valve lever all the way out, and close the churn valve lever. Open the discharge valves to the lines being used and accelerate the motor to maintain 750 pounds per square inch. Open slightly the cooling valve to the motor.

(2) FOAM OPERATIONS. These are the same as those described in b (2) above.

d. Personnel placement and duties for class 135 fire truck (fig. 8). The placement of men and their duties are the same as for the class 125 truck, except that rescue and hose men pull the hose from reels. To prevent the hose from fouling avoid spinning the reel.

e. Pump operations for class 135 fire truck. (1) FOG OPERATIONS. Set the hand brake, dismount, and go to the front of the truck. Engage the clutch by pulling the lever slowly upward to the "full" position while the motor idles. If the lever stops at the halfway mark, lower the lever and repeat the operation until the clutch is fully engaged. Accelerate the motor to a fast idle, open both intake valves fully, and pull out the lever marked "primer" until pressure is indicated on gauge. Release the primer lever, open the discharge valves at the pump, and accelerate the motor to develop a pressure of 350 pounds per square inch. Keep the reel valves open except on the rear reel, which is used for foam.

(2) FOAM OPERATIONS. On this truck foam is dumped from cans in the proportion of 20 gallons to 300 gallons of water. To mix the foam solution, open slightly the agitator valve between the cab and the tank on the truck. When the solution has been mixed for about 20 seconds, close the valve to maintain the pressure.

f. Personnel placement and duties for class 1010 trailer with weapons carrier (fig. 9). (1) No. 1, section chief, rides on the right front seat of the weapons carrier. Upon arrival at the crash he makes a size-up and directs the section's operations.

(2) No. 2, the pump operator, rides on the right rear of the weapons carrier. He operates the pump and watches closely all operations instruments and all working parts of the pump and engine. He is on the alert for hand signals from the crash site.

(3) No. 3, a rescue and hose man, rides on the right front of the weapons carrier bed. He removes the coiled hose from the rear of the trailer, places it on the ground, and pays it out. Then he goes to the crash with the crash kit and asbestos suit. He follows the chief's orders for rescue and other operations.

(4) No. 4, the driver of the weapons carrier and right-side nozzle man, drives the vehicle to the operation area. He dismounts, grasps the right-side nozzle, and advances the hose to the scene of the crash.

(5) No. 5, a rescue and hose man, rides on the left rear of the weapons carrier. His duties are the same as those of No. 3.

(6) No. 6, the nozzle man, rides on left front of the weapons carrier. He grasps the nozzle on the left side and advances the hose to the scene of the crash.

g. Pump operations for class 1010 trailer. (1) FOG OPERATIONS. Set the trailer hand brake, start the trailer pump motor, pull out the lever marked "suction inlet," open the discharge valves and turn the pressure-release valve clockwise until closed. The motor is governor-controlled to maintain operating pressure.

(2) FOAM OPERATIONS. Follow the same steps as are taken for fog operations, adding 10 gallons of foam solution to 150 gallons of

water in the tank. Fog guns are replaced by foam nozzles. Operate the pump at 280 pounds per square inch.

115. CRASH RESCUE KIT: TOOLS AND USES (fig. 53). **a.** The crash kit is removed from the apparatus by rescue men and taken to the scene of the crash. With the tools exposed, the roll is placed where it is readily available for use in forcible entry.

(1) The ax is used to free trapped personnel by cutting away metal sidings or doors.

(2) The sledge is used for striking heavy blows and for breaking plexi-glass, rivets, and locks.

(3) The hacksaw is used to cut metal bars, rods, sheet metal, and the like.

(4) The hand saw is used in cutting light metal or wood parts.

(5) The wrecking bar is used for prying, forcing, and other entry work. It is provided with a hook end for pulling hasps and forcing locks. It has a raised spur on the shank for greater leverage and a claw-shaped wedge for prying.

(6) The tinners' shears are used for cutting light metal.

(7) The pipe cutter is used to cut pipes, iron rods, and similar objects.

(8) The bolt clipper is used for cutting small bolts, rods, and strut wires.

(9) The side-cutting pliers are used to cut small wires and cables.

(10) The 1-quart carbon tetrachloride extinguisher is used to put out small fires.

(11) The hunting knife is provided for cutting leather straps and parachute straps, safety belts, or other fabric equipment which hinders removal of personnel.

(12) The shockproof and vaporproof flashlights are for use at night.

b. Crash rescue belt (fig. 54). Special rescue belts are provided crash rescue personnel so they may have immediate access to a variety of tools to effect entry and disengage and remove personnel or vital material from burning planes. In addition to assorted small entry tools, essential equipment consists of a special hand ax for opening and removing the metal covering of planes and a special sheath knife for slashing safety belts, parachute harness, clothing, or other material.

c. Other useful tools are carried on the trucks.

(1) A grapnel hook assembly is used to change the position of the plane to aid in rescue and fire-fighting operations (fig. 55).

(2) A 100-foot coil of ¾-inch rope is provided.

(3) The pickhead ax can be used as either a pick or ax.

(4) The claw tool is same as the crowbar, but can be used on heavier objects.

1. *Hand saw.*
2. *Ax.*
3. *Pipe cutter.*
4. *Vaporproof flashlights.*
5. *Carbon tetrachloride extinguishers.*
6. *Sledge.*
7. *Wrecking bar.*
8. *Bolt clipper.*
9. *Sheath knife.*
10. *Side-cutting pliers.*
11. *Tin snips.*
12. *Hacksaw.*
13. *Hacksaw blade.*

Figure 53. Crash rescue kit.

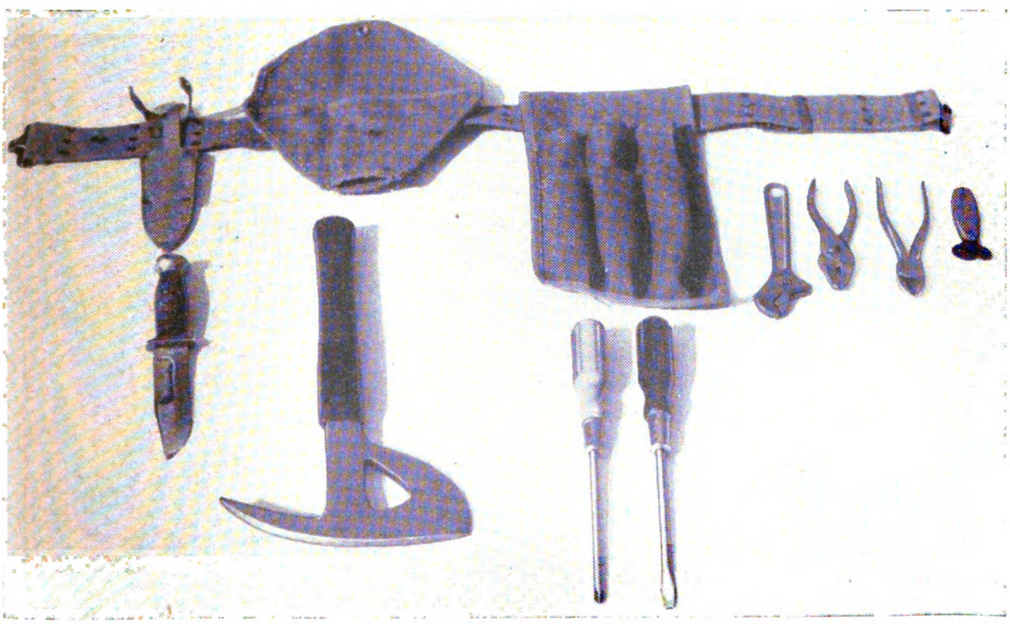


Figure 54. Crash rescue belt and tools.

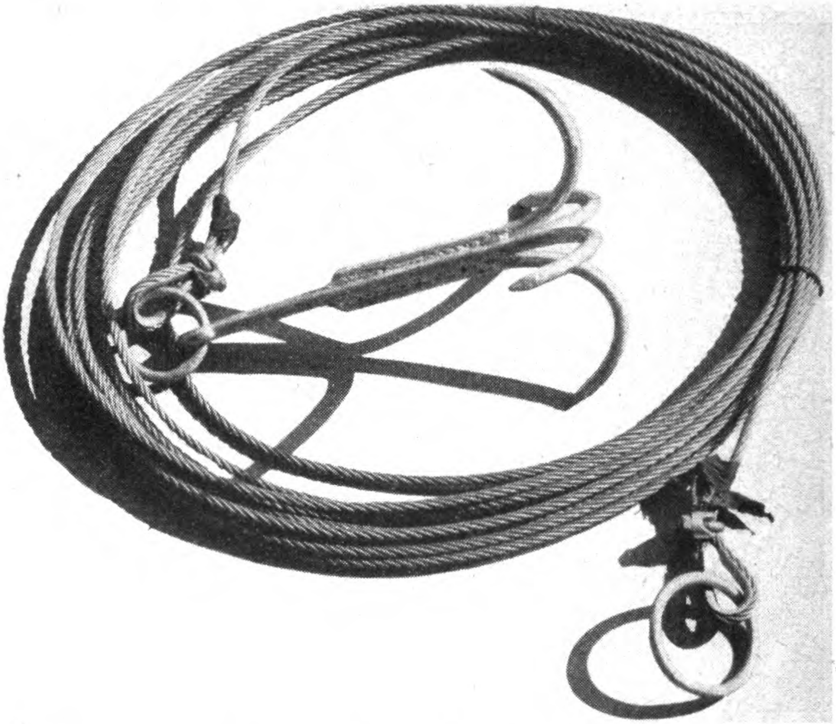


Figure 55. Grapnel hook assembly.

116. CRASH PROCEDURE. a. Aircraft crash without fire (fig. 56). No two crashes are exactly alike. Frequently aircraft do not burn for some time after a crash. However, the hazard is great and precautions against fire are taken immediately. Recommended crash procedure is outlined as follows:

(1) Drive truck to windward side of crashed aircraft. With rear of truck toward crash the grapnel hook can be used to move airplane for rescue or fire-fighting operations.

(2) Extend hose lines and stand by for operations.

(3) Remove any personnel from airplane (figs. 58 to 65, incl.).

(4) Turn off all electrical switches in airplane.

(5) Remove batteries by either disconnecting or cutting cables, *ground cable first.*

(6) Shut off all gasoline fuel valves. Be careful not to release dump valve.

(7) If gasoline is leaking, either blanket it with foam or sweep it away with high-pressure water.

(8) Plug small gasoline leaks with tapered plugs.

(9) Remove all gasoline. This is done by pumping to a gasoline truck.

(10) See that a guard is posted to prevent smoking within 200 feet of crash area.

(11) See that ordnance personnel remove bombs and ammunition.

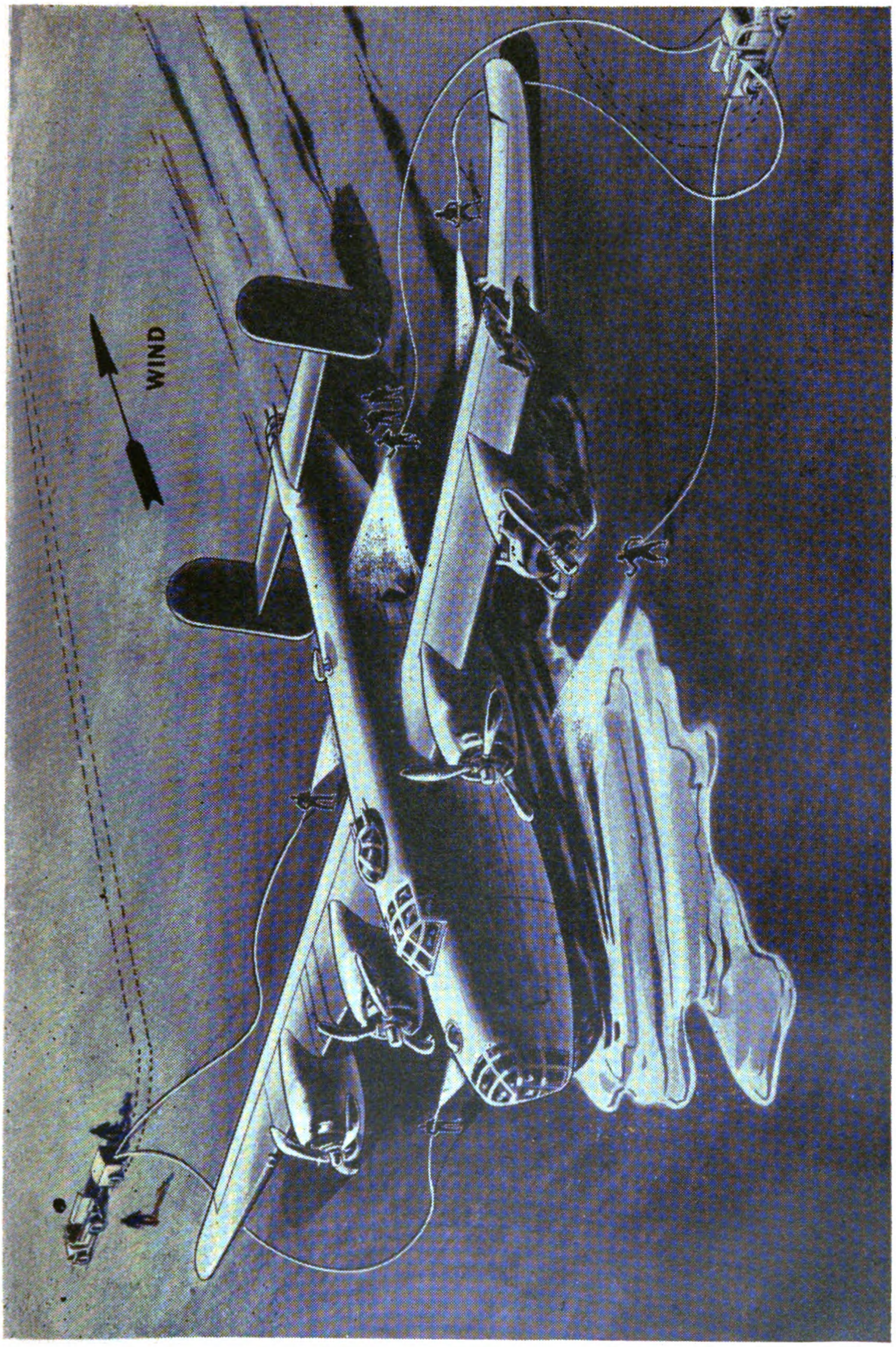


Figure 56. Method of handling a crash in which gasoline has spilled under the left wing of the airplane but has not ignited.

b. Aircraft crash with fire (fig. 57). Rescue of personnel and control of fire are effected in several different ways. When personnel can be rescued from the windward side, rescue and fire-fighting operations can be combined. This is an ideal situation as it allows the maximum utilization of equipment. When personnel must be rescued from the leeward side of the fire, part of the fire-fighting effort is required on the windward side. Great caution is taken to protect the

rescue crews. In approaching the fire, all available water streams are directed under the fuselage to sweep away the fire and gasoline. Once close to the fire, fog streams are converged ahead of the advancing rescue crew. To the flanks, overlapping fog streams cover the entire operation. With the rescue achieved, the fire is extinguished by working gradually around the airplane. Foam streams are held on extinguished areas to prevent reflash.

Figure 57. A method of handling a crash in which the two motors on left side have caught fire.

c. Starting and warm-up fires. Fires caused by backfire and ignition of excess gasoline from over-carburization or engine-starting failure are prevalent in modern military airplanes. So far as practicable, aircraft engines should never be started without a fire extinguisher immediately available. Either the CO_2 or carbon tetrachloride fire extinguishers are effective on this type of fire. If fire results from starting, but the engine starts, the fire can often be extinguished by creating propeller wash; or, if the fire is burning in the exhaust pipe system it can frequently be blown out by the compression in the exhaust system. Carbon dioxide, if used, can be applied effectively to the front of the engine with the propeller idling slightly, but not enough to dissipate the gas too rapidly. Under ordinary conditions, CO_2 is best used with propellers idle, being applied as close as possible to the seat of the fire from the windward side. Carbon tetrachloride is often effectively applied between the propeller and the engine, utilizing the wash of the propeller to vaporize and force the vapor back through the engine. On some models of airplanes carbon tetrachloride streams can be introduced directly to the inside of engine cowling or even through the exhaust piping. Perfection of operation can be achieved only through actual experience.

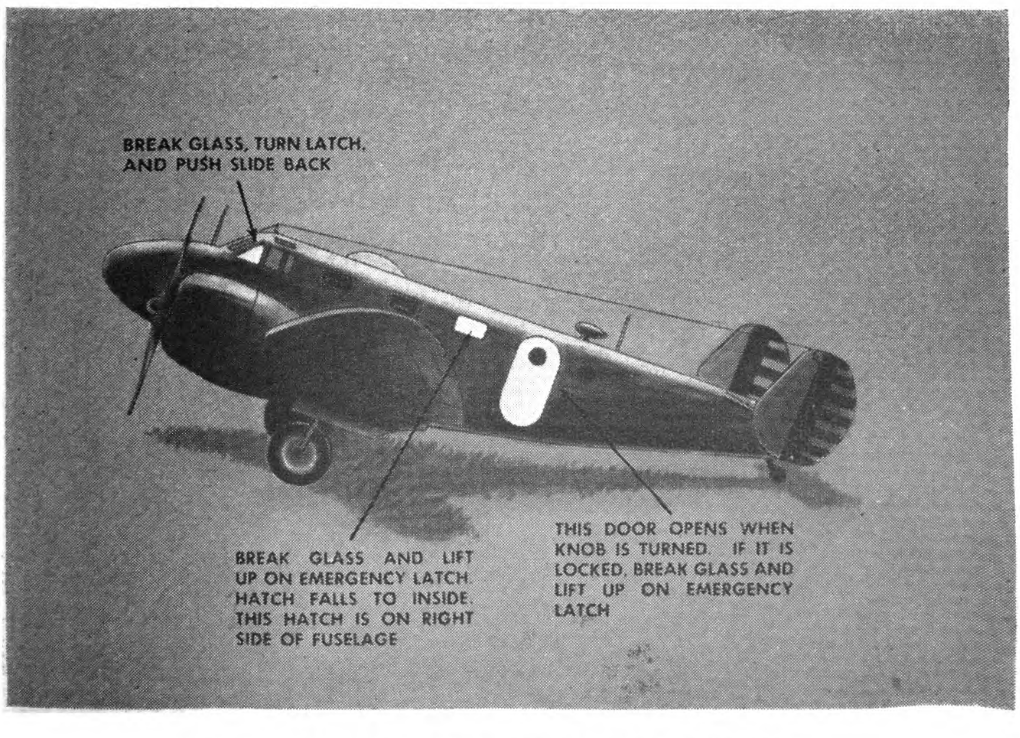


Figure 58. Points for entering an AT–7 airplane.

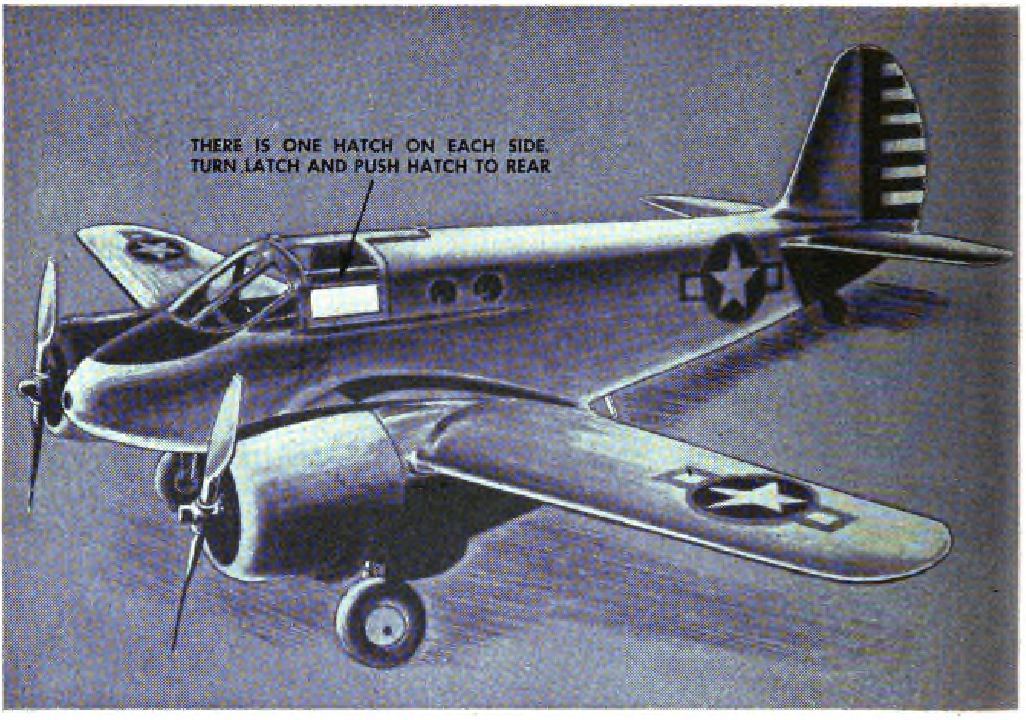


Figure 59. Points for entering an AT–10 airplane.

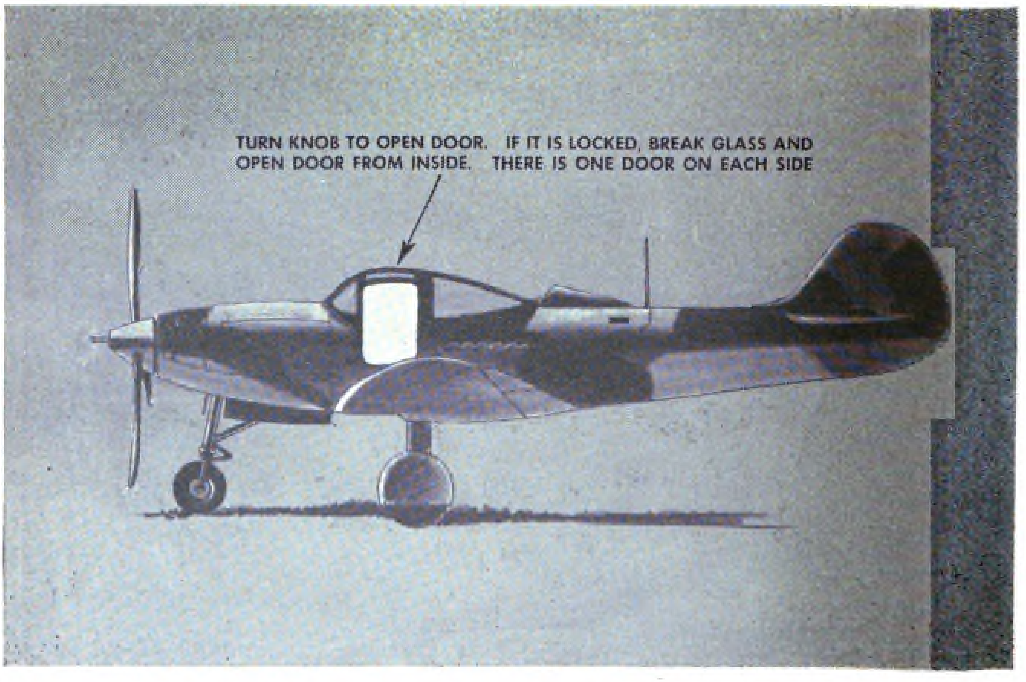


Figure 60. Points for entering a P–39, P–40, or similar ***airplane.***

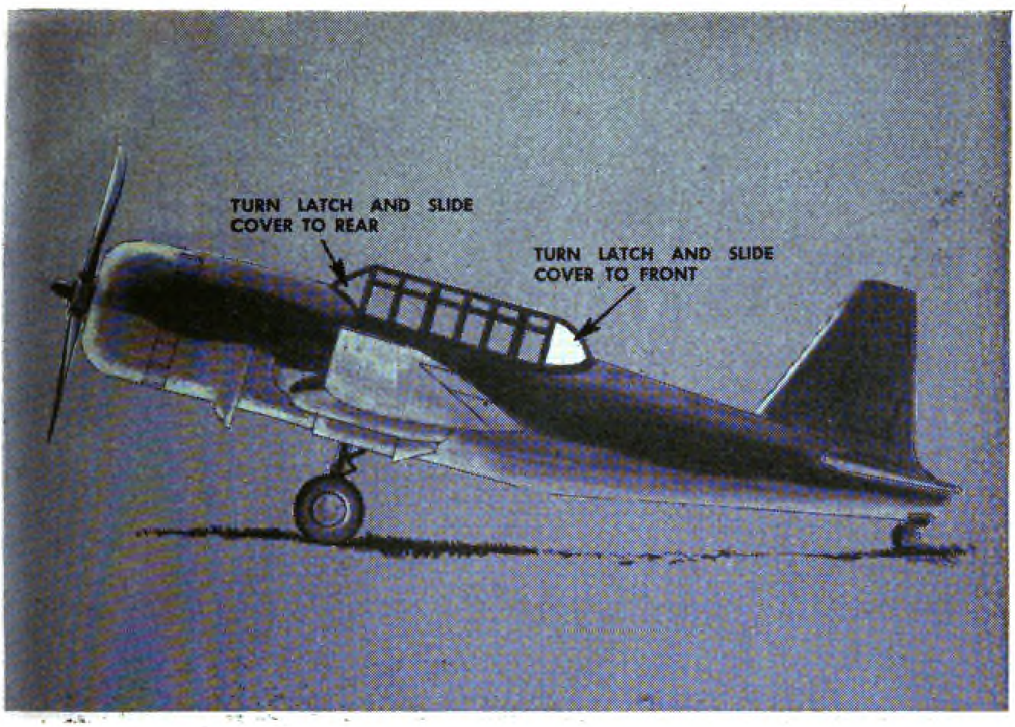


Figure 61. Points for entering an A–31 airplane.

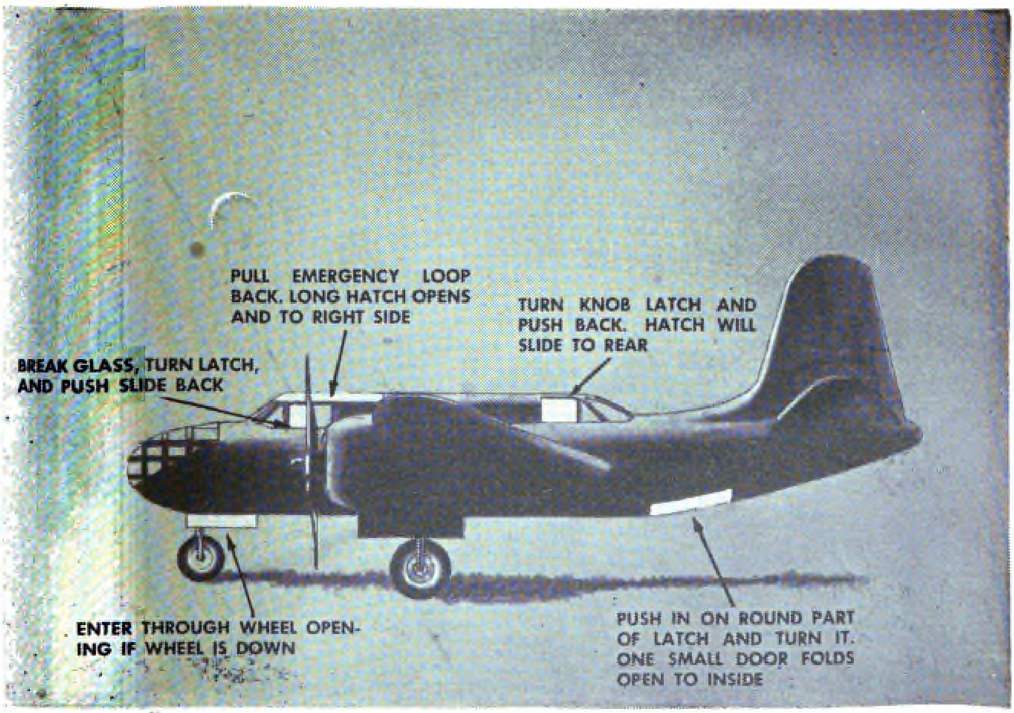


Figure 62. Points for entering an A–20 airplane.

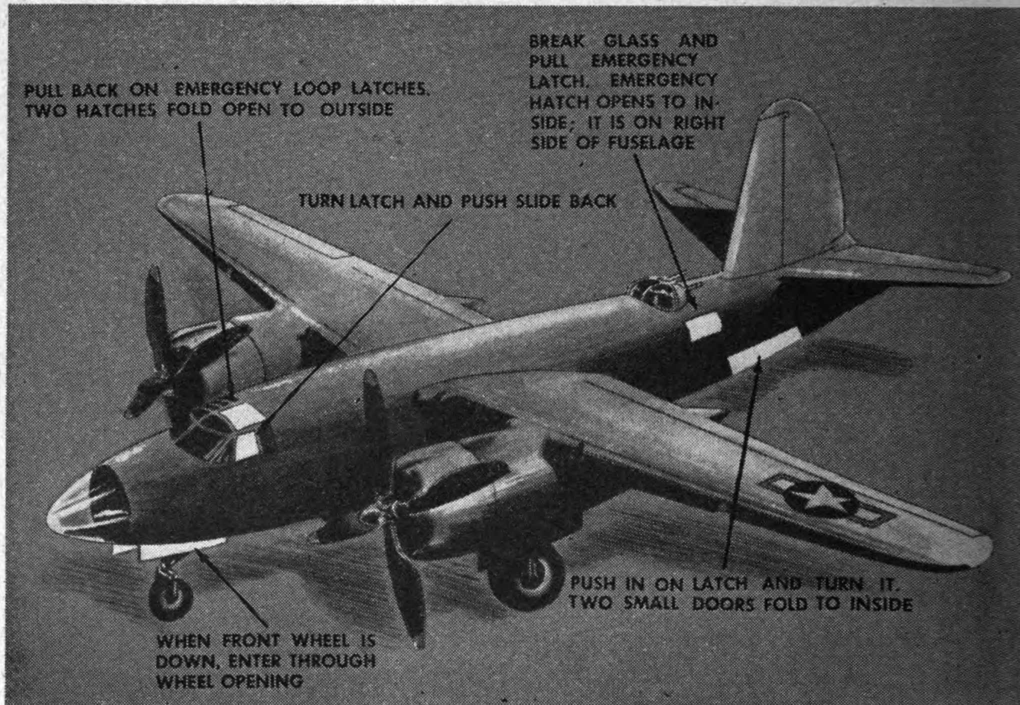


Figure 63. Points for entering a B–26 airplane.

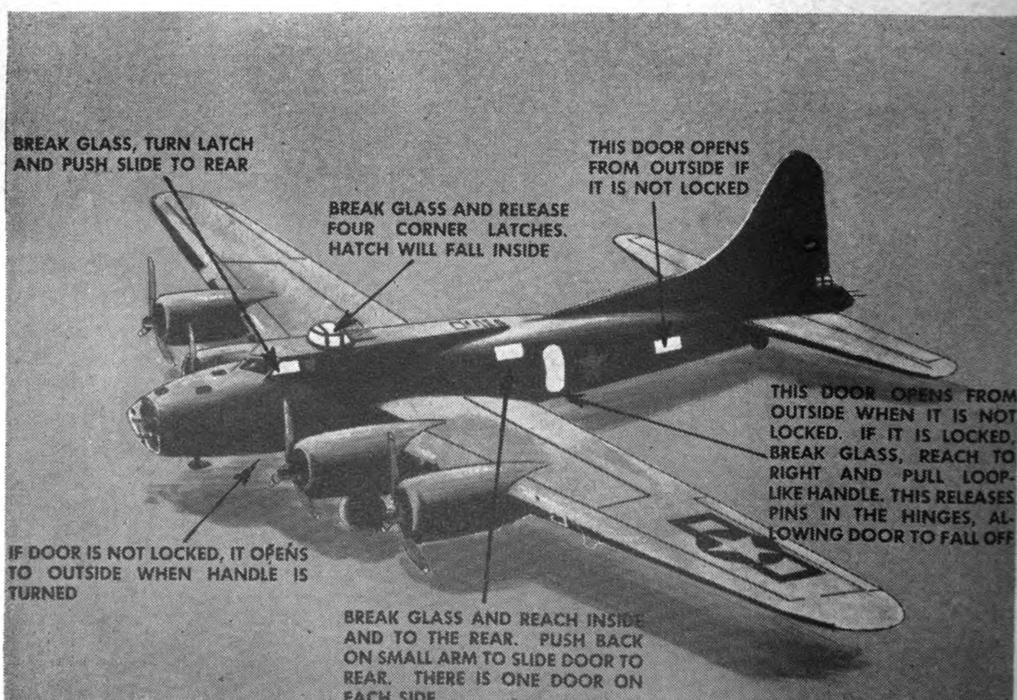


Figure 64. Points for entering a B–17 airplane.

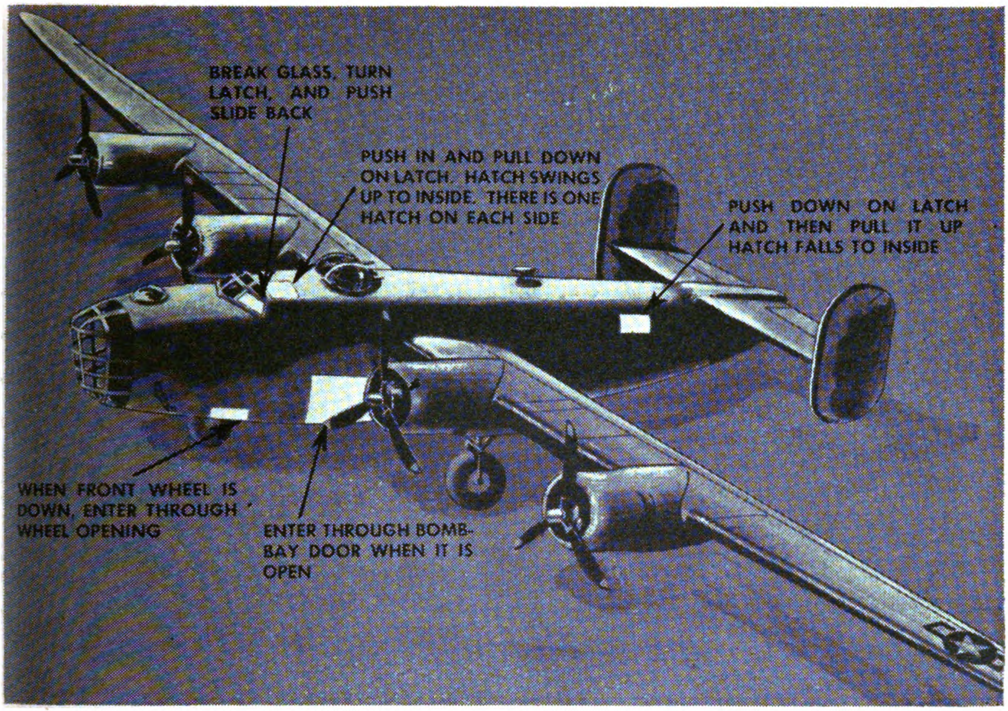


Figure 65. Points for entering a B–24 or C–87 airplane.

SECTION X
CONTROL OF NATURAL-COVER FIRES

117. GENERAL. Natural cover may be grass, weeds, grain, brush, forest, or other plant life. Incendiary bombs, flares, tracer bullets, and high explosives ignite these readily combustible materials upon contact. This danger is particularly acute in dry climates and during dry seasons. The potential damage of this type of fire is much greater than that of fires in buildings. In natural cover fuel is plentiful and fires may cover hundreds of square miles. Because of the waste of raw material, camouflage facilities, military equipment and installations, lives of personnel, and the manpower needed to check a large fire, the necessity for quick control of natural cover fires is apparent. Only by immediate action can they be controlled with a minimum of manpower and equipment.

118. DEFINITIONS (fig. 66). **a. Fire line.** Natural cover fires move rapidly. The perimeter or fire line is the hottest part of the fire. The interior is a smoldering mass with only a few flames and many glowing

embers or sparks. Natural cover fires are best controlled along the fire line. As it increases many times faster than the area covered, a small fire must be controlled early.

b. Head. The point where the fire line is progressing fastest is called the head. A natural cover fire may have any number of heads depending on the type, abundance, and location of the fuel. Fire heads generally travel with the wind, and the stronger the wind the greater the speed. Due to frequent directional changes of the wind, varying types and quantities of fuel, and topographic conditions, natural cover fires have irregular perimeters, making control difficult and often dangerous.

c. Tail. The upwind portion of the fire is called the tail. This is the point where the progress of the fire is slowest. Usually it is near the origin of the fire.

d. Flank. All portions of the fire line between the tail and the various heads, and those slower burning sections between heads, are called flanks.

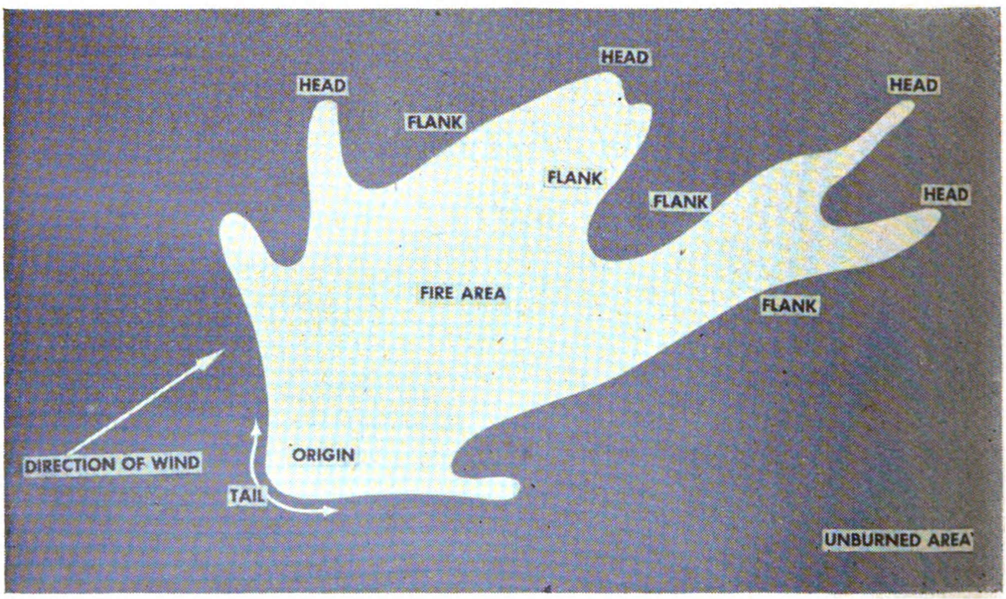


Figure 66. Terminology of natural cover fires.

119. GENERAL CHARACTERISTICS OF NATURAL-COVER FIRES.

The rate of burning of natural cover fires depends mainly on the velocity of the wind, type and abundance of fuel, and general topographic conditions.

a. The head of the fire travels at a rate proportional to wind velocity. Wind carries additional oxygen to the fire and increases the rate of ignition. The hot air rising from the fire causes a partial

vacuum. Cold air with a fresh supply of oxygen rushes in at the base. The larger and hotter the fire, the stronger this natural draft.

b. Fire heads move faster uphill and up draws or canyons than on level ground or downhill. Heads running uphill dry out and vaporize fuel faster than on level ground or down slopes. The upward rush of cold air acts like the draft in a chimney and speeds ignition accordingly. Heads running up draws, valleys, or canyons cause the inrush of cold air with a new oxygen supply to be concentrated in a small area and as a result the speed is increased. It is much like a forced draft in a blacksmith forge, fanning the fire to greater speed and intensity. Men or equipment never should approach the head of a fire from down wind when the approach necessitates travel in a draw, valley, or canyon.

c. A running fire should never be controlled from the uphill direction. This entails a high risk to men and equipment. The correct point to begin control is at the tail on the upwind side of the fire line or at the head of the fire when it tops a crest and begins to burn downhill. A fire burns slowest downhill. The natural draft is counter to the direction of run, making it possible to control the fire before the head gains new momentum.

120. TYPES OF NATURAL COVER FIRES. a. Ground fires. These are fires which travel at ground level. Dry leaves, humus, peat, and other organic materials which have become part of the soil are the fuel. Ground fires move slowly and are more or less simple to control.

b. Surface fires. Surface fires are fires in grass, weeds, grain, brush, and shrubs. This type fire travels rapidly if the wind is high and fuel dry and abundant. The heat is intense but short-lived because of the flash burning of these fuels.

c. Crown fires. Crown fires are fires in the tops of trees and high brush. When the heat generated by flash fuels at the surface is intense the fire runs up dried lower limbs of trees and burns in the tree tops. This occurs mostly in coniferous forests and then only on steep slopes, in draws and canyons, or during high winds. This is the most dreaded of all natural cover fires. The enormous flames suck oxygen from the air for hundreds of yards from the fire line and generate such intense heat that direct control is impossible. Indirect methods such as fire breaks, either natural or man-made, and backfiring, are the best means of controlling large crown fires.

d. Spot fires. Spot fires are fires started in advance of the heads by wind-blown sparks or bits of burning material. This creates a dangerous situation. A number of spot fires may merge and cause a new head in advance of the main fire. Men and equipment may be

trapped between these fires and large losses may result. A well-organized patrol must be on the alert to locate spot fires and get them under control before any damage results.

121. TOOLS AND EQUIPMENT. a. General. Tools and equipment include pioneer hand tools and field expedients. Such tools are supplied to the various engineer organizations.

Pioneer Tools	*Special Equipment*
Axes	Back-pack pumps.
Saws	Burlap or canvas.
Peaveys or cant hooks	Brooms.
Shovels	Rakes and hoes.
Pickmattocks	Tractors, plows, drags, graders.
Brush hooks and scythes	Bulldozers.

b. Special Army equipment. Both the engineer fire-fighting platoon and the engineer aviation fire-fighting platoon are equipped with fire or crash trucks having 300-gallon booster tanks or class 1,010 crash trailers with 150-gallon tanks for use on natural cover fires. Converted decontaminators M1 or M4 also may be used. Auxiliary hand tools, pump tanks, and back-pack pumps are of assistance. In some instances the class 1,000 pumper and weapons carrier combination can be used to make long relays of water.

122. SUPERVISION AND LABOR. Supervision of natural-cover fires may be provided by the personnel of engineer fire fighting platoons. Enlisted men of any branch may be used as labor when necessary, under proper authority. The engineer fire fighting personnel of a platoon may be sufficient if small fires are attacked at once. Combat engineer organizations have trained leaders and equipment readily adaptable for fire fighting. *Supervisory personnel* of the engineer fire fighting platoons consists of the platoon commander, the staff sergeant, and four section chiefs. Competent fire fighters may also supervise enlisted men from other branches.

123. DIRECT METHOD OF CONTROL. a. Direct attack. When the progress of a fire is slow, or the fuel is scattered and short and there are only small flames, the direct attack may be used. The heat usually is insufficient to drive the fire fighters away from the line. The initial attack may be on any part of the fire line.

b. Parallel attack. The parallel attack is used on fast-running fires in any cover to avoid their great heat and smoke. The initial attack is made at the tail of the fire while control units work along flanks and gradually close in to pinch out the head or heads.

c. Organization of attack. There are two general methods of organization for attacking a natural cover fire.

(1) SECTIONAL METHOD. A unit is placed on a specific section of the fire line. Its mission is to stop the progress of the fire, extinguish the fire line, and execute mop-up and patrol work. The unit has full responsibility for that section of the fire line.

(2) "ONE-LICK" METHOD. This is the fastest and easiest method to use on a running fire. A unit is placed on the fire line and ordered to work in a specific direction. From one to several men of a unit knock down the hottest portions of the fire with back-pack pumps and proceed along on the flank. Behind the pump unit several men tear up the ground with mattocks. By "leap-frogging" a continuous line of disturbed earth is created. Men with shovels then dig out the loosened earth. They throw combustible material away from the fire line and spread the soil with a flinging motion on the burning portion of the fire line. This knocks down and extinguishes the fire. Earth must be shoveled with force to spread it as far as possible. A large shovelful of earth is required only on a hot spot. Any burning bits of humus, leaves, or rotted wood are thrown into the fire. In this manner a clear trench down to mineral soil is extended along the fire line. The width of the trench varies with the intensity of the fire. Behind the shovel men are one or two axmen who sever any tree roots or buried or rotten logs extending across the trench. All material that will carry fire over the trench is eliminated. Last, one man is left to patrol a specific section of controlled line. He may have a back pump and a shovel or other equipment to prevent any flare-up from jumping the line and starting new fires.

d. Modifications. (1) There are many variations of this method according to the type of fire encountered. In timberland, felling crews with saws and axes may be the first in line. Other ax and saw crews may have to cut paths or lines through windfalls or down timber. In heavy brush it may be necessary to cut lines along the flank of the fire with brush hooks or axes before control is possible.

(2) Grass fires in fields and prairies require a different organization of men, tools, and equipment. Here back pumps, wet burlap, or strips of canvas or shirts are used to beat out the fire. In the "one-lick" method each man performs a specific operation at intervals along the line and keeps moving from the tail along the flanks toward the head of the fire. When the last man of the unit passes any point, the fire must be in complete control behind him.

(3) One popular modification of the parallel and direct methods is the "2-foot" method used on only moderately hot fires. Either the "sectional" or the "one-lick" attack may be used. The men are able to

approach closely and clear a line through brush and woods and dig a trench about 2 feet from the fire line, about 2 feet wide, and deep enough to reach mineral soil. Mineral soil is spread on the fire and organic soil thrown away from the fire. If any piece of organic soil is burning, it is thrown inside the fire line.

(4) Grass and grain fires are sometimes controlled by plowing furrows or by making fire breaks along the fire lines with bulldozers or graders. Lines are patrolled by men beating out the fire with shovels, burlap sacks, or tree branches. Drags are sometimes pulled behind tractors or other vehicles. Plows and drags also can be used in brush lands when the brush is small enough to permit maneuvering heavy equipment.

(5) Fires in flooded meadows and marshlands may be checked quickly by marching a group of men along the outside of the fire line. The grass and rushes are trampled into the water or muddy ground to prevent ignition.

124. TOOLS AND EQUIPMENT. **a.** Engineer fire-fighting platoons are equipped with fire trucks containing booster tanks, which may form the spearhead of the "one-lick" method of attack on almost any ground or cover. They may be used also for furnishing water to the fire lines either by tank or by ground hose lines.

b. Weapons carriers may be used to drag plows or improvised drags over grass, grain, or small brush fires. If fire trucks and crash trailers are used to spearhead the "one-lick" method, they can supply a steady stream of water for a few minutes only. Back-up lines from the pumper trailers should be laid if a source of water is available. The booster lines must be fastened on the sides of the trucks or weapons carriers to prevent dragging on the ground. They may be tied with rope or secured by running the line around projections on the vehicle. The nozzle of the forward line must be about 15 feet ahead and to one side of the vehicle. The rear nozzle is operated on a line with the rear of the vehicle. The driver regulates the speed to the progress of the lead man.

c. The stream of water must be diffused. The fog or high-pressure nozzle using the fog cone furnishes the best stream. If only a straight stream is available, it may be broken by holding the thumb or a piece of wood or tin over the nozzle tip to cause a spray.

d. Men with back-pack pumps follow the vehicle to knock down any remaining hot portions of the fire. Men with shovels, tree branches, burlap sacks, or brooms, follow along to beat out the last remaining flames or sparks. Patrolmen complete the operations.

125. INDIRECT METHODS OF CONTROL. **a.** The indirect method entails the use of firebreaks or barriers. Natural fire barriers are lakes,

rivers, creeks, deserts, or bare rock formations. These barriers will halt a natural-cover fire, if sufficiently wide to prevent spread by spot fires. Natural barriers may be augmented by artificial fire breaks.

b. Artificial firebreaks may be roads, highways, survey lines, transmission lines, or cleared areas. Specific lines may be cut for preventing the progress of fires. Firebreaks must be at least twice as wide as the height of the immediate cover types. They should be cleared to conform as nearly as possible with the ridge lines and to connect natural barriers. Firebreaks must be cleared of brush and grass to prevent fire traveling through these flash fuels. Most permanent firebreaks have small truck trails built in conjunction with them.

c. Backfires are employed where a suitable network of firebreaks exists. Backfiring should not be attempted except on the orders of an officer who has had wide experience in this operation. Improper backfiring causes loss of control of the fire and may trap personnel working on the line. Great damage and loss of life and equipment may result. The whereabouts of all men and equipment must be known before any backfiring is started. Before lighting a backfire, sufficient men and equipment must be on the job to control the conflagration. Wind direction and velocity must be considered in conjunction with either natural or artificial firebreaks. Whenever possible the backfire should run uphill and reach the ridge about the same time as the head of the original fire. At this point the main fire may be halted. Backfires may be started with matches in dry cover, by using oil-soaked torches, or by flame throwers, if available.

126. ESTIMATING THE SITUATION OR SIZING UP NATURAL COVER FIRES. The first step in control of a natural-cover fire is to determine its perimeter or fire line so that the men and equipment required may be estimated properly.

a. Note the type, density and flammability of the fuel. This indicates the type of fire heads to be encountered.

b. Note the velocity and direction of the wind. This indicates the speed of the fire and the direction of the heads.

c. Topographic features are important. Locate ridge lines, swamps, rivers, lakes, roads, and other breaks in the vicinity. A quick map check of the terrain is a valuable aid to fire-fighting operations. All possible lines of control are considered.

d. Estimate the probable paths of new fire heads and the possibilities of spot fires. Men and equipment must never be sent into a situation where their loss is possible.

e. Note the water supply. Provisions must be made for replenishing the water in booster tanks and back-pack pumps and supplying drinking water. In addition, each man must carry his canteen full.

f. Estimate the need for additional fire-fighting units, labor and equipment. Obtain help if control is uncertain.

g. Locate a safe line of retreat. Always have a way out for personnel and equipment.

h. Taking all factors into consideration, decide upon a point of attack and the method of control, and begin operations immediately.

i. Know the whereabouts of personnel and equipment at all times. Keep in touch with all units during the fire-fighting operations.

127. PATROLS. **a. Patrol of controlled fire lines.** When the fire is under control and the main fire-fighting unit is working elsewhere, provision is made to prevent the fire from jumping the controlled line. A system of posts is designated and a man patrols each post. The patrolman is provided with a back-pack pump and a shovel and other available equipment to protect his post area. He must be alert and resourceful. To assure proper patrolling of the post system, a sector patrolman supervises a number of posts. The number and length of the posts are determined by the nature of the fire and the terrain.

b. Patrols outside the fire line. A well-organized patrol covers the ground for several hundred yards outside the fire lines. It searches for spot fires and controls and extinguishes them if possible. When the spot fire is large it is reported to the officer in command for proper action.

128. MOPPING UP. Mopping up is the extinguishing of every spark or cinder on the fire grounds. When the entire fire line is under control and all progress of fire heads is stopped mopping up is begun. Inside the line a mass of burning embers, smoking stumps, logs, and partially burned foliage may flare up with the first gust of wind. Mopping up is done by the band method. A band extending a certain distance inside the fire line is mopped up first. Other bands of specified width are covered successively until the entire burned area has been covered and the last spark extinguished. The procedure is as follows:

a. Due to irregularities of the fire line, many small patches of unburned fuels remain inside. If there is any danger of a flare-up after the main control unit has passed, the area is burned out under capable supervision to prevent a jump-over.

b. Single stumps and logs are carried a good distance inside the line, torn apart, and extinguished with water, or covered with mineral soil. When they cannot be moved a trench is dug around them to the mineral soil and the hazard covered with mineral soil.

c. Concentrations of logs, stumps, or similar fuels are separated and spread out and treated as single hazards.

d. Stump craters are holes in the ground where large stumps have burned out. The holes left by the burned roots probably are full of burning embers. These holes are filled and packed with mineral soil to smother the fire and prevent outbursts of flame.

e. Burning snags and spike trees standing near the fire line are felled and treated by trenching and burying with mineral soil. Burning snags well within the fire line are treated the same way, since sparks from these snags are carried a long distance by the wind and may start spark fires.

f. All dry sod, manure, and strawstacks are soaked thoroughly with water and treated by the trenching and covering methods.

g. All burning objects on side hills are trenched deeply enough to catch any burning embers that may roll down hill and across the fire line.

h. After all evidence of smoke, flame, and sparks has disappeared a small patrol is retained on duty for 1 or 2 days to prevent any outbreak of the fire.

CHAPTER 5

FIRE PROTECTION

SECTION I
THEATER REQUIREMENTS

129. TACTICAL CONSIDERATIONS. The fire-defense requirements of an installation not specifically subject to enemy air attack are much less than for one subject to such attack. An important installation near an active theater and subject to saturation air raids requires maximum fire organization and protection; one of secondary importance subject to occasional raids requires less than maximum protection but more than normally is required where such hazards do not exist.

130. FIRE STATION LOCATION. a. Ground installations. Fire station location depends upon the hazards involved, the distance the apparatus has to travel, condition of roads, topography, and other local conditions. In general, no vital installation should be farther than the following distance (or time) from a fire station:

Type of facility	*Distance*	*Time*
Isolated barracks and living quarters....	3 miles	12 minutes
Congested barracks and living quarters	1½ miles	8 minutes
Warehouse and shops..............................	¾ mile	5 minutes
Hospital	½ mile	3 minutes

b. Air force installations. The platoon headquarters, the headquarters section, and one section may be located at the main field. Two sections may be located at the main field or may service satellite or emergency landing fields. The class 1010 and class 1020 truck trailers are small enough to be airborne in an emergency for protection of distant or captured fields.

SECTION II
MANPOWER REQUIREMENTS

131. ORGANIZATION PERSONNEL. Since one platoon can man and equip only four fire stations, additional platoons may be necessary for large installations. Each section of a platoon has only sufficient personnel to operate efficiently during fires. Sickness, casualties, meal times, fire prevention inspections, and other duties deplete the manpower available for duty. Provision for periodic relief from duty by trained personnel must be made for each section. Having no mess personnel or equipment, the platoon is attached to other units for mess. It performs only its own fatigue.

132. AUXILIARY FIREMEN. **a.** Each platoon leader recommends requirements in additional fire-fighting personnel to the commander of the unit to which attached. Training of auxiliary firemen is a responsibility of the platoon commander. Since duty as auxiliaries will be in addition to regularly assigned tasks, training activities and fire-fighting practice are coordinated with unit commanders to avoid conflict with normal duties.

b. The normal requirement of auxiliary firemen is one fire party per building in the installation. These parties are controlled by block leaders, who are responsible for mobilizing and directing block personnel prior to arrival of regular fire-fighting units. Although basically part of the passive defense organization, fire parties depend on fire-fighting units for training.

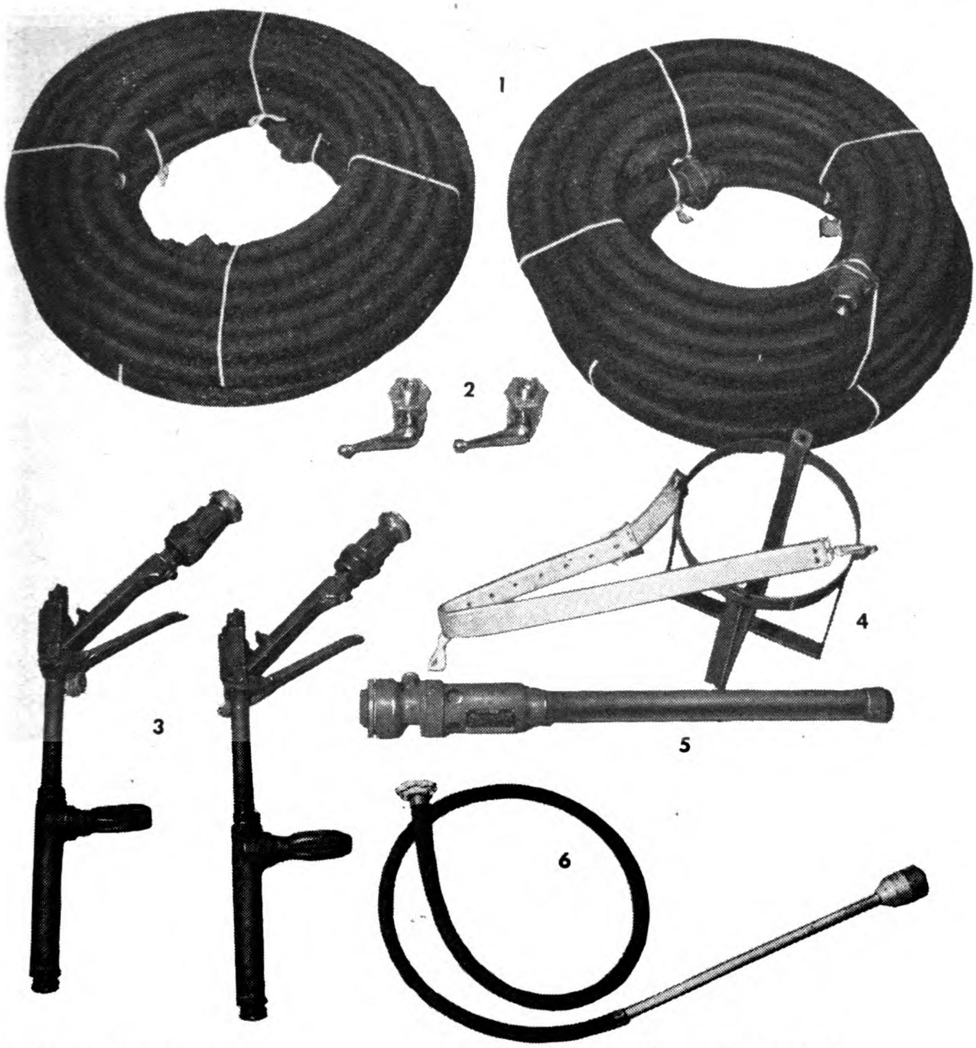
SECTION III
PUMPER AND WATER REQUIREMENTS

133. PUMPER REQUIREMENTS. The total pumper capacity necessary for adequate fire protection depends upon structural conditions, materiel to be protected, and the available water supply. When a water system can supply an adequate quantity of water at a minimum flowing pressure of 75 pounds at the hydrant, and buildings are not more than four stories high, the sections may operate with hose lines connected to hydrants, without the use of pumpers. When the above conditions are not met, or buildings are located too far from the

hydrants, the water system is supplemented by pumpers. Where pumpers are required, their total capacity should equal two-thirds the required fire flow. For example, if the required fire flow of a subdivision is 1,500 gallons per minute, the pumpers must have a total capacity of 1,000 gallons per minute. Provision is made for utilizing water from ponds, streams, cisterns, or other artificial and natural sources. In determining the required pumping capacity, the area is subdivided, lightly built areas being separated from heavy concentrations of buildings and combustible material.

134. WATER REQUIREMENT. a. Ground installations. Fire flow is the quantity of water in excess of normal domestic consumption required for fire-fighting purposes. In case of fire, the water system furnishes water for a number of fire streams, depending upon the character and congestion of buildings and other combustibles. Each 2½-inch hose stream has a capacity of about 250 gallons per minute. Where no congestion exists and buildings are not high, two 2½-inch fire streams, requiring 500 gallons per minute, usually are adequate. Where buildings are less than 50 feet apart, 1,000 gallons per minute should be provided. Water supply, sufficient to provide full fire flow for more than one fire at a time, should be considered in a theater of operations exceeding 10,000 population. In active theaters subject to saturation air raids and bombardment, provision from auxiliary sources should be made for additional fires.

b. Air force installations. (1) Crash trucks carry 300-gallon booster tanks and the class 1010 and 1020 crash trailers each carry 150 gallons of water. Under favorable conditions the class 125 and 135 crash trucks each can operate two booster lines for about 5 minutes. The class 1010 and 1020 crash trailers each can operate two lines for about 2½ minutes. Class 125 and class 135 crash trucks, and class 1010 and class 1020 crash trailers, also are effective in controlling incipient and moderate sized fires involving buildings and ordinary combustibles, as well as airplane crashes.
(2) Rescue and fire-control operations require additional water supplies immediately available on the field. Provision must be made for hauling water onto the field in water carts, tank wagons, tank trailers, or decontaminators. The decontaminator M–1, with a capacity of 450 gallons of water, has a high-pressure pump and can be converted readily into an auxiliary crash truck. Information on the conversion is contained in War Department Training Circular No. 32, 1943. Information on conversion of decontaminators M3, A1 and M-4 is contained in War Department Training Circular No. 92, 1943 (fig. 67).
(3) When the air field has hydrants, additional water supply may be obtained by laying hose lines with the third section trailer and weapons



1. *High-pressure hose.*
2. *High-pressure valves.*
3. *Fog guns.*
4. *Sling and carrying basket.*
5. *Hip-pack nozzle.*
6. *Hip-pack tube.*

Figure 67. Crash fire-fighting conversion kit for mobile decontaminators.

carrier unit. Cisterns and wells can be located near the edges of the field to provide additional water if needed.

c. Adequacy and reliability. The water source must furnish all the water necessary to meet the combined domestic and fire requirements at any one time. In addition to failure for normal reasons, water systems in active theaters are subject to disruption by high-explosive bombing. Normal storage, duplicate pumps, duplicate power systems, and other safeguards may fail when saturation raids occur and break many water mains at one time. For this reason every effort must be made to provide sufficient auxiliary supplies and facilities to prevent the spread of a conflagration started by high-explosive and incendiary bombs, and to effect rapid emergency repair or redistribution to cut out damaged sections.

135. AUXILIARY WATER REQUIREMENTS. **a.** Most areas afford sources, and in many instances entire dependence for fire protection will be placed upon auxiliary water supplies from sources such as cooling tanks, ponds, water tanks, swimming pools, rivers, harbors, wells, brooks, stock tanks, basins, storage tanks, and cisterns. Portable canvas reservoirs, or improvised reservoirs consisting of tarpaulins suspended over a built-up framework placed in a hole in the ground, may be used to good advantage and may be moved from place to place as needed. In freezing temperatures reservoirs must be kept free of ice, to provide suction openings.

b. To make supplies quickly available, driveways or approaches must be provided to give ready access to the pumpers. Threaded outlets of the proper size and thread, or manholes for suction hose, may be needed at tanks. To permit pumpers to take suction promptly from rivers or harbors, permanently installed suction pipes of adequate size are desirable. They should have a screened intake well below water level at low tide and provided with properly capped and threaded suction connections. It may be desirable to pipe water by gravity from ponds to fire cisterns constructed in convenient locations. A basin or cistern is frequently necessary in a stream to impound water sufficiently deep to permit the suction line of a fire pumper to be properly immersed. Where streams or drainage ditches pass under or close to roads, stone-lined water holes or concrete cisterns may be located where they can be reached from the road by pumpers.

c. To be reliable, auxiliary water sources should be available in all seasons, and should be kept clean. Suction basins should not be located in the main path of a stream, as they become filled with stream deposits. Where streams or ditches become dry during dry seasons or droughts, cisterns may be arranged to fill during wet seasons for storage. Such cisterns require tight walls and covers to prevent evaporation.

d. When preparing pumper accommodations consideration should be given to the reliability of water supply and its convenience to the buildings or material to be protected. Auxiliary water supplies more than 750 feet away do not afford good protection. Time lost in making long hose-line lays, limitations of hose available, increased pumping pressures, and increased requirements in pumping equipment must be considered. Long relays of water should be avoided if other means of obtaining it can be developed. For example, the class 1000 pumper trailer delivers approximately 500 gallons per minute at the required minimum of 50 pounds pressure at the nozzles of two streams through 500 feet of 2½-inch fire hose. At 1,000 feet the capacity of the pump is reduced to 250 gallons per minute, doubling the number of pumps necessary to deliver 500 gallons per minute at the fire. At 1,350 feet the capacity of the pump is reduced to 167 gallons per minute, and

the requirement is tripled. The latter delivery requires 250-pound pressure at the pump. Such high pressure requires the best grade of double-jacket fire hose, in good condition, and such hose is not always available in active theaters.

e. In places of secondary importance the minimum suction supply of cisterns or other sources of stored water is 3,000 gallons. This will supply a ½-inch nozzle for 1 hour. Larger storage supplies are desirable, and in important locations are imperative.

SECTION IV

FIRE AND CRASH ALARMS

136. FIRE ALARMS. At permanent Army installations, fire alarms are transmitted by a special fire-reporting telephone system from street telephone boxes direct to the central fire station, whence they are redistributed to other stations. At the larger installations in a theater of operations, such Signal Corps facilities may be available. However, it is probable that most installations in active theaters must depend upon regular field telephone or improvised alarm facilities similar to, but distinctive from, air-raid and gas-alarm devices. Telephone fire-alarm systems generally are not considered adequate, since mixed traffic may result in delays in reporting fires, or prevent a report altogether. Installation of private lines to switchboards at fire headquarters offers a partial solution. Maintenance of communications over any wire system during air raids will be discontinuous, and breaks will occur when the line is needed most. Runners, mounted or on foot, must be held in readiness during air raids to supplement or replace wire communication. Radio communication, when available and not prevented by radio silence, assists greatly in maintaining communication.

137. CRASH ALARMS. Depending on local regulations, crash alarms are given by the air field operations control facilities or by direct observation of the crash sections. Other means of communication are field telephones and radios. It may be desirable to install one-way radios on crash trucks, tuned to the same band used by the aircraft. Other fire alarms are handled in the same manner as for ground force installations.

SECTION V
FIRE PREVENTION

138. GENERAL. Most ordinary fires are caused by carelessness or ignorance and are controllable at the start. By proper building construction and arrangement, and by adequate protection, practically all such fires can be prevented from causing appreciable damage. The prevention and protection problem resolves itself into preventing the outbreak and serious spread of fire, and providing for its prompt detection and extinguishment. Illustrations of the types of problems that require mature fire protection judgment are:

a. Special hazards.

b. Water supplies.

c. Structural conditions.

d. Storage of munitions and inflammable liquids.

139. FIRE HAZARDS. **a.** Rubbish and waste materials of various kinds contribute to a large number of fires and are frequently classified as a fire cause although, except in the case of spontaneous ignition, such material does not cause fires but furnishes the tinder for ignition by small sources of heat and for the spread of incipient fires.

b. A high standard of cleanliness and order, especially the proper and regular disposal of waste paper and other combustible materials, is perhaps the most important single element in fire prevention.

c. Many oils, cleaning compounds, paints, and other materials are subject to spontaneous ignition. All such materials should be handled with care. Oily mops and rags should be kept in metal containers.

d. Smoking is the most common fire cause, and the match is the largest element in this hazard. Matches may cause fire by friction in pockets or by being stepped on. The kind which strike only on the box are safest. Smoking should be prohibited where the building and its contents are combustible.

e. Wooden supply cupboards are fire hazards in such places as machine and paint shops, where the woodwork becomes oil- or paint-soaked and where clothes or oily waste will be left in critical places.

f. Clean cotton waste is generally considered to be mildly hazardous, being readily flammable when not baled, and there is always a chance that dirty waste may become mixed with it. Waste should be kept in metal bins with self-closing covers which are kept closed, and not in clothes lockers, drawers, and on benches.

g. Excelsior, straw, sawdust, and burlap are all dangerous, and should be treated similarly to clean waste.

h. Oily waste, oily clothing, and wiping rags, particularly if containing quick-burning oils subject to spontaneous ignition, are highly dangerous. Oily sawdust and lint also are subject to spontaneous ignition.

140. SAFE STORAGE METHODS. a. General. Large amounts of materials should be dispersed in several piles and not stored in one place. Fire will not cause total loss if the various classes of supplies are stored systematically. It is better to protect some of the material and prevent total loss than to take a chance and lose the entire supply.

b. Storage precautions. (1) Food should be stored in a safe place, and not all in the same location. Aisles and passageways should be of sufficient size to permit access to any part of the storage space. A pile of goods should have a space of at least 18 inches between its top and the ceiling. When materials are located in the open as in beach-head landings, the piles should be placed at least 10 feet apart to allow fire apparatus to cover the entire supply on all sides in case of fire. This also facilitates removal to a safe location of the material not involved in the fire.

(2) Fire extinguishers should be available in all store rooms to control fire at its outbreak. Instructions should provide for fire-fighting headquarters to be called before attempting extinguishment.

(3) Signs should be placed where special precautions are necessary. "No smoking" signs and signs giving the procedure in case of fire should be conspicuously displayed. Metal containers, plainly marked "Rubbish" and "Clean Waste," should be placed where needed.

(4) All personnel should report violations of fire regulations to the responsible person in charge without delay.

c. Fuels. Engine fuels, lubricants, gasoline, and coal, should be stored separately. Gasoline and oil drums should be stacked on end in small piles. The end of the drum is its weakest point, and the possibility of ruptured drums causing the spread of fire over a wide area thus is prevented to a great extent. Inflammable liquids should be placed on a slope, away from danger, so that the liquid will drain off in a safe direction. When storage is large, it should be separated into groups as small as practicable and earthen dykes should be erected around each group to confine burning limits to single areas or groups.

d. Ammunition. All types of ammunition should be stored in isolated areas, in several piles, with spaces between large enough to allow trucks to pass through to extinguish a fire present or to move exposed material to a safe place.

141. ARMY AIR FORCES. a. Fire rules. To minimize the fire hazards in the buildings and on the grounds of the Army Air Forces, the following rules will be strictly followed:

(1) When airplanes are brought into a repair shop or hangar for repairs or for storage, however brief, after having been serviced with gasoline, great care will be taken to prevent the overflow of the gasoline tanks from expansion due to changes of temperature. Airplanes will not be refueled, or drained of gasoline, while inside buildings. When fueling, airplanes should be removed as far as possible from each other to avoid involving more than one airplane in case of fire.

(2) Gasoline trucks, whether loaded or empty, will neither enter nor be stored in hangars. They will be parked within 100 feet of hangars, paint and dope shops, fuel storage systems, or other critical installations only long enough to load or unload their cargo. Gasoline trucks should not be parked in groups, but should be separated as far as practicable.

(3) Drums and other receptacles containing gasoline, oil, dope, paints, or varnishes, will not be kept in hangars or other buildings where aircraft or inflammable aircraft parts are stored. Small quantities of certain of these materials may be kept available for immediate use if safety containers are used.

(4) Airplanes and other equipment will be cleaned with inflammable materials only under competent supervision, as prescribed by existing Technical Orders, with ample fire extinguishers at hand.

(5) Oily rags, waste, trash, and other matter which might cause spontaneous combustion will be kept in covered metal receptacles which are emptied at least once each day and always prior to closing the hangar or building.

(6) When weather conditions, temperatures, or dust make it advisable to do so, airplanes may be serviced with oil while in hangars, but care will be taken not to spill oil on the floors or allow it to accumulate in drip pans or other containers.

(7) When other facilities are not available, aircraft may be painted in hangars. It will be the responsibility of the commanding officer to exercise necessary precautions to insure safety of personnel and Government property.

(8) Certain gases or vapors, like those from gasoline, normally settle to the floor; while others, like hydrogen, rise to the ceiling. Such characteristics of liquids or gases should be noted by those dealing with them, and appropriate precautions taken. A gas or vapor explosion may occur just as easily from the action of a tool spark, a spark from the nail of a shoe, or a static electrical discharge, as from a match or a blowtorch. While the extensive use of nonferrous metals in airplane construction reduces tool sparks to a minimum, such metals are not immune to static charges. While airplane casings are purposely made

with electric-current-carrying characteristics, when an airplane is resting on a dry concrete runway or floor this characteristic is not entirely dependable, and an airplane standing in a hangar can be electrically charged by the motion of air over its surfaces. Merely the touch of a hand may then permit discharge of an invisible spark which will cause an explosion if the surrounding atmosphere is vapor-laden. This condition is more likely to exist during cold, dry weather than during warm days. In winter particularly, if gasoline vapors are unavoidable, steps should be taken effectively to "ground" each airplane, preferably to a water pipe. Building structural members are not necessarily grounded unless water piping is mounted on them.

(9) Use of blowtorches or other equipment where open flames are employed will be carefully restricted to isolated places in hangars and other buildings where there is good circulation of air and where no combustible vapors will be encountered. This equipment should not be used to repair any aircraft until it has been ascertained that there are no leaks in its fueling system or in that of nearby aircraft.

(10) Open-flame heating units will not be used in shops, such as paint and dope shops, handling inflammable material. However, such heating units may be used in hangars and other shops.

(11) While working where gasoline or other combustible fumes might be encountered, vaporproof and explosionproof lamp assemblies will be used exclusively. No portable type lamp assembly will be used in any maintenance shelter without a proper guard or wire shield to protect it against breaking. Special caution will be taken to prevent accidentally making or breaking electrical connections.

(12) In all buildings where gasoline piping and equipment are utilized, or where inflammable or volatile liquids are used, stored, or handled in other than their original containers, adequate natural or forced ventilation will be provided. Where unit heaters are installed primarily for heating purposes, in summer such units should be operated without heat, for ventilating purposes.

(13) Radio transmitters installed in aircraft will not be tested or operated with dynamotor running, unless all parts of the antenna system are at least 1 foot away from any other object. Except when absolutely necessary, no airplane will be placed at any time so that any fabric-covered surface is within 1 foot of the antenna system of any airplane.

(14) Wherever practicable, fire extinguishers will be made available while aircraft engines are started.

(15) Except where specifically constructed smoking rooms have been provided for that purpose, smoking or striking matches will not be permitted within 50 feet of parked aircraft; during fueling, the loading or unloading of tank trucks or the filling of storage tanks from pipe line, tank trucks, or tank cars; or in hangars, shops, or other buildings

in which highly inflammable materials are stored or used. Signs covering fire protection instructions, with letters not less than 2 inches high placed on a suitable background so that they can be read from a distance, will be posted in conspicuous places at the entrance and in and around all buildings in which aircraft or highly inflammable materials are stored or likely to be used. All tank trucks will carry like warning signs, which will be posted at either end of the truck while standing or loading or delivering gas on Government grounds.

(16) Commanding officers of all depots and stations will require the post engineer or the fire marshal to make an inspection and report on conditions at least once each 30 days, giving special attention to adequacy of fire extinguishers and their distribution to meet emergencies; to determine the training and competency of operating personnel in all units required to handle highly inflammable materials; to determine their knowledge of the use, singularly or in combination, of prescribed fire-fighting equipment, and to determine the existence of any carelessness or failure to observe and carry out regulations and technical orders pertaining thereto.

CHAPTER 6

PASSIVE AIR-DEFENSE AND FIRE-DEFENSE MEASURES FOR MILITARY INSTALLATIONS

SECTION I
GENERAL

142. PLANNING. **a.** Each depot, camp, or other installation presents a different fire-defense and passive air-defense problem. Because of the disruption to normal activity caused by air raids it is necessary to consider the other phases of passive defense when making a plan. These factors are:
(1) Frequency and severity of probable air raids.
(2) Available protective aircraft and antiaircraft defense.
(3) Relative value of installation.
(4) Size of installation.
(5) Population.
(6) Type of buildings.
(7) Type of materials stored in area.
(8) Water supply, both primary and auxiliary.
(9) Available fire-fighting equipment.
(10) Communication facilities.
(11) Road network and its condition.
(12) State of training of troops.

b. Fire defense and passive air defense of any Army installation are the responsibility of the commanding officer. Evolving an effective plan requires the cooperation and coordination of the fire-defense officer, fire marshal, post engineer, provost marshal, post surgeon, and those responsible for the control of the passive air-defense organization.

143. STANDING ORDERS. **a. Passive air defense.** Standing orders set up standardized procedures to be followed in event of an air raid. They include—

(1) Standard warning signals for air raids.
(2) Blackout regulations.
(3) Assignment of air-raid precaution personnel.
(4) Location and assignment of air-raid shelters.
(5) Traffic regulations.
(6) Assignment of repair crews.
(7) Bomb disposal measures.
(8) Gas warning system.

b. Fire Defense. In addition to passive air-defense measures standing orders establish fire parties, fire leaders, and wardens for each subdivision of the area, and provide for their training and use during fires whether caused by enemy air attack or other factors.

144. DISPOSITION OF FIRE-FIGHTING EQUIPMENT. For effective fire defense in an area subject to air attack, equipment must be dispersed so that one direct bomb hit can immobilize no more than one piece of apparatus. Other factors to be considered are installations, relative value, and susceptibility to damage; communications to the proposed locations; the road net and its probable loss of usefulness during and after the air raid; type of supplies and material stored in the areas; and location in respect to other equipment which may act in support of the unit in question.

145. WARDENS. Fire- and air-defense warden organizations usually are broken down geographically into sector or area wardens, block wardens, and building or barrack wardens. Building wardens are provided only for buildings that will be occupied during a raid, except for the senior block warden on duty in his block during a raid. In addition to fire and bomb reporting, wardens may be used to enforce blackout regulations or rules governing the movement of personnel. Fire parties are organized within the warden's organization, but are trained by the fire-fighting personnel of the post.

146. MESSENGERS. To provide communication during interruptions to wire lines during an air raid, messengers are provided and trained under the supervision of the post signal officer. Standing orders provide for their dispatch to wardens' posts and to critical areas on the post.

147. MILITARY POLICE. For passive defense, military police are fully mobilized to control traffic, to assist in orderly movement of personnel to and from shelters, and to prevent depredations during the air raid.

148. MEDICAL PERSONNEL. Medical service is of vital importance during and after air attacks. Sufficient personnel must be available to care rapidly for those injured. Dispersed ambulance service is necessary for rapid collection and evacuation of casualties from devastated areas. First-aid posts and first-aid parties located throughout the occupied area care for minor injuries, preventing congestion of the hospital facilities.

149. POST ENGINEER. The post engineer is charged with rescue, demolitions, clearance of debris, and maintenance and repair of communications and utilities. The post engineer coordinates the activities of the fire-fighting units and other troops under his command. Engineer troop units stationed in the camp may be assigned missions in connection with air raids, but necessarily are a less permanent part of the post engineer's plan because of the frequent changes of station of units in the theater of operation.

SECTION II

FIRE-DEFENSE AND PASSIVE-DEFENSE PLANS—MAXIMUM FACILITIES

150. GENERAL. The following plans for the passive defense of mythical "Camp Marshal" represent the use of the maximum facilities and equipment available in a theater of operations. This discussion is presented for comparison with the methods, outlined in the next section, of a fire-fighting unit in an advanced oversea base.

151. DESCRIPTION (fig. 68). **a.** Camp Marshal is located a considerable distance from a combat zone, but is within flying distance of enemy bases and subject to air attack at any time. The camp is located between a good highway and a navigable arm of the ocean and consists of 1,200 acres of land in an otherwise undeveloped area. The nearest city, 12 miles to the south, has a population of 114,000 and the normal utilities and fire protection, including a fireboat. The fireboat can be sent to Camp Marshal.

b. All necessary utilities are furnished by the camp itself. A large oil-burning power plant supplies electricity, steam, and hot water. A pumping station pumps well water into a 250,000-gallon elevated steel tank. The station is equipped with both Diesel and

electric pumps, so arranged that if the storage tank is destroyed water can be pumped directly into the distribution system. Water is furnished to the camp through a crisscrossed system having a fire hydrant in every block. Forty miles of asphalt macadam road insure all-weather communications in the camp area. The camp has rail and water terminal facilities.

c. Piers and bulkheads are concrete. Sheds, warehouses, barracks, and other buildings in the camp are of frame construction. All are

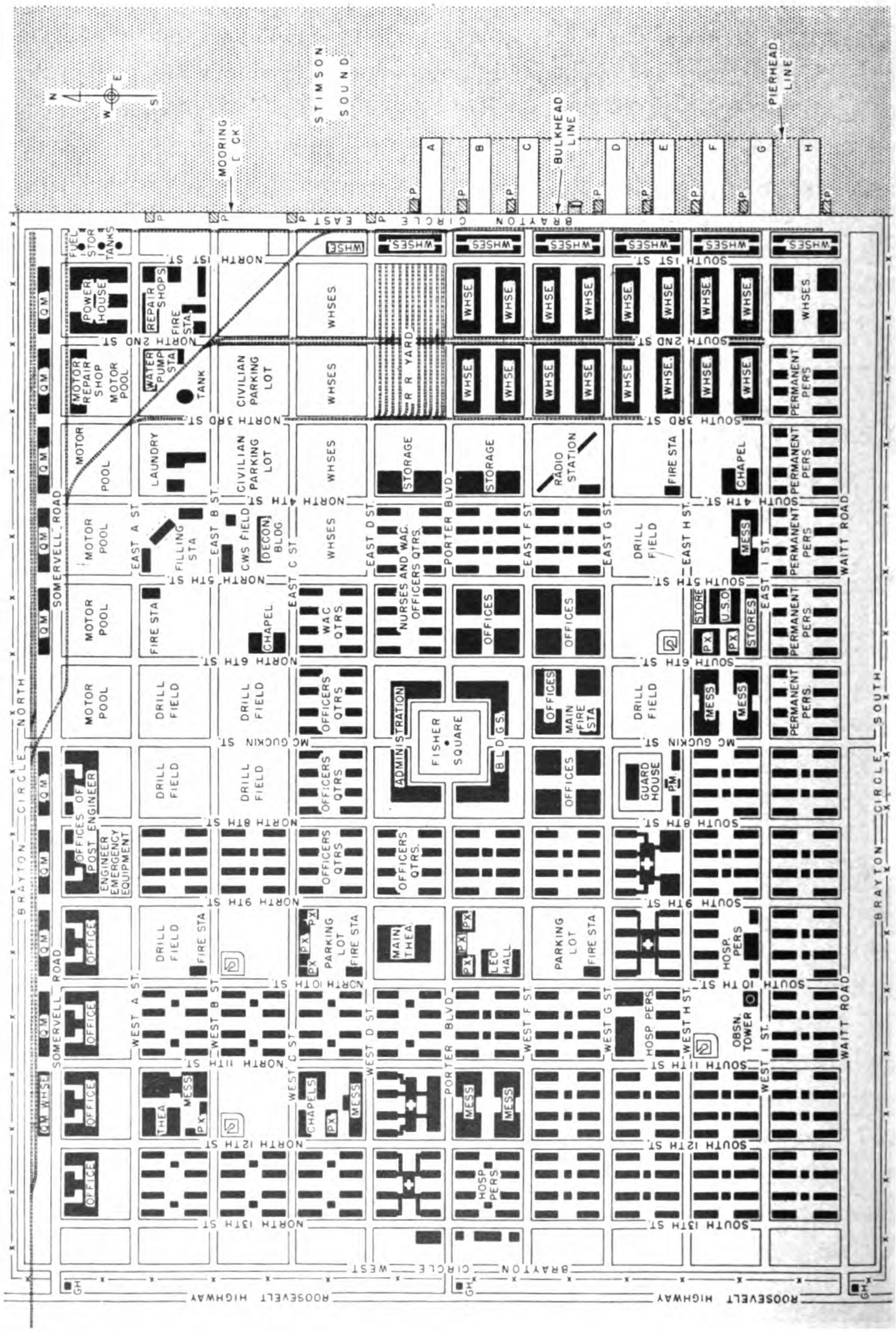


Figure 68. Plan of Camp Marshal.

one story high except the barracks which are of two-story construction.

d. The telephone system provides an extension to every block on which there is at least one building. In the administration building, office buildings, and hospital, extensions are numerous. In the barracks area there is a telephone in each orderly room. From the switchboard in the northeast administration building on Fisher Square there are 600 telephone extensions. The switchboard is connected to the exchange at Johnson City by 30 trunk lines. In addition to telephone service the camp is connected with the War Department teletype circuit and has a direct line to the Army Information Center. The radio station is independently powered to avoid interruptions to the electrical system. An independent telephone system powered by wet-cell batteries connects seven fire stations with the main fire station. The main fire station is connected to the main switchboard by three extensions and one independent hand-crank telephone line.

e. Of a total population of 94,250, 83,200 are transient. The hospital has 800 beds.

f. Camp Marshal is an important post from which entire task forces are dispatched after assembly and processing. The installation is definitely an enemy target and lies within the area which could be attacked from the air. Hence, antiaircraft, searchlight, and smoke units have been stationed in the area. Aircraft warning service is provided for these units.

152. PASSIVE AIR-DEFENSE ORGANIZATION. a. Standing orders. The Commanding Officer of Camp Marshal has issued standing orders pertaining to the passive air-defense organization of the camp. His orders specifically state the number of personnel and kind of training necessary for such an organization. The standing orders also state what mobilizations and activations will take place on the various air-raid alarms.

b. Fire. (1) The fire protection forces for Camp Marshal consist of two engineer fire-fighting platoons. Each platoon has four pumpers. The pumpers are located at fire stations as follows:

Northeast corner, North 2d Street and East B Street.
Northwest corner, North 4th Street and Porter Boulevard.
Northeast corner, South 4th Street and East H Street.
Southwest corner, North 5th Street and East A Street.
Northeast corner McGuckin Street and East A Street.
Northwest corner, North 10th Street and West B Street.
Northwest corner, North 10th Street and West D Street.
Northwest corner, North 10th Street and West G Street.

(2) In addition to the above-mentioned pumpers, there are twenty-eight auxiliary pump units, each manned by two operators. All auxiliary

fire pumps are located where they can take suction at low tide. They are distributed as follows:

(*a*) Eight auxiliary pumps have been placed upon individual floats moored to the docks. The floats can be moved from dock to dock by a 25-foot launch. Near each dock are two hose reels, each manned on the blue alarm by six auxiliary fire fighters. Four auxiliary pumps have been placed permanently along the bulkhead line at the following locations:

Brayton Circle, East and East A Street.
Brayton Circle, East and East B Street.
Brayton Circle, East and East C Street.
Brayton Circle, East and East D Street.

(*b*) Sixteen auxiliary pumps are stored in the post engineer yard located on the north side of West A Street between North 8th and North 9th Streets. They are mounted on rollers on a platform so that they can be rolled onto 2½-ton trucks. Two men, in addition to the driver, are assigned to each truck. They assist the driver in loading the pump. They remain with the vehicle and act as pump operator and helper. Auxiliary fire hose, 1,000 feet per auxiliary pumper, is stored in specially constructed wooden hose beds, mounted on rollers for easy transfer to truck beds.

(3) If the motor pool is unable to furnish a hose truck for each pumper, one truck for every two pumpers can be made to serve. Auxiliary fire-fighting personnel, together with the truck drivers, report to the post engineer upon sounding of the blue alarm. They load their pumps and hose and, without further orders, proceed to predetermined locations, provided with telephone connections, as follows:

Two hose wagons and pumpers to powerhouse at Somervell Road and North 4th Street.

One hose wagon and pumper to Motor Pool at Somervell Road and North 4th Street.

One hose wagon and pumper to Motor Pool at Somervell Road and McGuckin Street.

Two hose wagons and pumpers stay at Post Engineer's parking yard on West A Street between North 8th and North 9th Streets.

One hose wagon and pumper to office building at Somervell Road and North 10th Street.

One hose wagon and pumper to warehouse at East F Street at Brayton Circle East.

One hose wagon and pumper to warehouse at East F and South 2d Streets.

One hose wagon and pumper to radio station at F and South 4th Streets.

One hose wagon and pumper to office at East F and South 6th Streets.

One hose wagon and pumper to barracks at West F and South 8th Streets.

One hose wagon and pumper to parking lot at West F and South 10th Streets.

One hose wagon and pumper to mess hall at West F and South 12th Streets.

One hose wagon and pumper to shop at East B and North 1st Streets.

One hose wagon and pumper to warehouse at East H and South 1st Streets.

The pumpers will report to fire headquarters upon arrival at their locations. Both the regular and auxiliary pumpers are under the control of the senior fire officer. The senior fire officer reports to and remains with the post engineer at the control center. The regular pumpers are manned constantly, whereas the auxiliary pumping units are manned only on the blue alarm.

(4) In addition to the above-mentioned equipment and personnel, 800 fire parties have been organized. There is at least one fire party to every building. A fire party consists of—

Four men, including a leader.
One hand pump.
One hand ax.
One crowbar.
Two buckets with water.

A noncommissioned officer, the block fire leader, acts as leader for all of the fire parties in a block. In the absence of the block senior warden the block fire leader calls the control center to report fires. The fire parties are part of the warden organization. However, they are trained in fire fighting by instructors assigned by the senior fire-fighting officer. The fire parties are given practice in fire fighting during air-raid drills.

(5) An observation post, equipped with a telephone line to the main switchboard, has been established on top of the water tower. This post is manned constantly by at least two men. These observers have been trained in fire recognition by the senior fire officer. Another observation post, also manned by at least two observers, has been constructed on the northwest corner of South 10th and West I Streets. This post is a 60-foot wooden tower equipped with a telephone. The observers at this point can see any part of the camp. The observers at the observation posts have been instructed to report the approach of hostile planes, parachute flares in the sky, large fires within the camp, and other developments of interest to the control center.

(6) A direct line has been installed from the telephone switchboard at

post headquarters to the fireboat headquarters at Johnson City.

(7) The following equipment and supplies are placed about the camp in buildings:

1,568 shovels.
1,568 sand containers.
1,568 water buckets, filled at all times.
1,500 soda acid fire extinguishers.
75 feet of hose for every standpipe.

c. Wardens. (1) A complete warden's organization has been established in the camp. The warden organization has been broken down geographically into sector or area wardens, block wardens, and building or barrack wardens. Wardens are on duty only in those buildings in which personnel are present at the time of a raid. The senior block warden is on duty at a telephone in his block. With him is an assistant block warden. All reports to control center from wardens or fireguards are given by the senior block warden. In those blocks where there are no wardens assigned, the block fire leader handles the reports to the control center. His headquarters also is at a telephone.

(2) The wardens have been instructed in their basic duties during an air raid. They have been trained in the methods of transmitting a clear and concise report to the control center. Wardens also perform duties such as enforcing blackout regulations.

(3) An officer is assigned to every block of the camp. It is his duty to see that all orders of the camp and from the control center are carried out. The officers report to their blocks on the blue alarm and remain until relieved by higher authorities.

d. Messengers. A group of well-trained messengers have been developed at the camp under the supervision of the post signal officer. A messenger reports to every block on the post which has a telephone, to carry messages to the control center if the telephone system fails. Messengers also are stationed at the control center, the hospital, and the fire stations.

e. Military police. The military police have been well trained in their duties during an air raid. All military police on the post are mobilized on the blue warning. Upon mobilization they proceed to their posts. Military police are always in pairs.

f. Medical. (1) The doctors, nurses, and hospital personnel have been well trained by the post surgeon in their duties during an air raid. The staff is mobilized in successive stages at the command of the post surgeon. All medical personnel are on call during an emergency.

(2) Ambulances mobilize under a plan developed by the post surgeon. This plan calls for the distribution of ambulances about the post. If the ambulance service becomes overtaxed, the post transportation officer

has made plans to supply the post surgeon with additional vehicles from the motor pool. Sixteen ambulances have been assigned to the passive air-defense organization of the camp. Four ambulances are assigned to each sector; they make their headquarters at the sector first-aid post.

(3) The four first-aid posts are mobilized on the blue warning. There is one post in each sector. One medical officer and four assistants are assigned to each post. Sixty-four first-aid parties have been organized. Sixteen are assigned to each sector. There are four men to a party and two stretchers per party. An emergency morgue is organized in the warehouse building at the corner of South 1st Street and Waitt Road.

(4) Triangular steel gas alarms with hammers attached for sounding them have been mounted on every block of the camp.

(5) Decontaminating stations for wounded have been set up next to the receiving rooms at the hospital; and one for uninjured personnel needing decontamination, on the chemical warfare service field.

g. Decontamination. A decontamination station has been provided for by the post chemical warfare officer. He has made arrangements to use the gasoline filling station at East A Street and North 4th Street for this purpose.

h. Post engineer. (1) The post engineer is charged with rescue, demolition, clearance, maintenance, and repair. The senior fire officer is under his supervision.

(2) Thirty-two engineer rescue squads have been organized and trained under the direction of the post engineer. They have received instruction in shoring, tunneling, and first aid. Eight squads are assigned to each sector. It has been recommended that they be distributed about the sector at locations having telephones. A squad consists of seven men with a truck for carrying their equipment and tools. The eight squads assigned to a sector report at the same depot to an officer in charge. A noncommissioned officer is in charge of each squad.

(3) The maintenance and repair forces of the camp have been organized to function immediately, particularly for the repair of shattered water mains.

i. Control center—passive air-defense command post. (1) The control center functions for and in behalf of the commanding officer; all orders from the control center bear his authority. The control center is located in a room next to the telephone switchboard room in the administration building on Fisher Square. The outside of the building has been sandbagged and the room has been strengthened to withstand bomb blast damage.

(2) The control table is an oval table with places for seven people and a telephone for each. The places are for the following personnel:

Commanding officer or Chief of Staff.

CAMP MARSHAL PANEL BOARD

		SECTOR						
		N.E.	3	5	8	16	4	
		S.E.	2	5	8	16	4	
		S.W.	1	3	8	16	4	
		N.W.	2	3	8	16	4	
INC. NO.	LOCATION	TIME OF INC.	FIRE PUMPERS	FIRE AUX. P'RS	RESCUE PARTIES	FIRST-AID PARTIES	AMBUL-ANCES	NOTES MISC.
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								

Figure 69. Control panel for use in passive defense.

Defense coordinator (executive officer).
Post engineer.
Senior fire officer.
Provost marshal.
Post surgeon.
Post Chemical Warfare Service officer.

(3) Besides those mentioned above as members of the control center staff, the following report to the control center to assist those exercising control:

Post ordnance officer.
Post signal officer.
Post transportation officer.
Post quartermaster.

(4) Also in the room are a map of the camp, drawn to the scale of 1:2,400, upon which are plotted all incidents, and a panel board showing the disposition of equipment and manpower for each incident (fig. 69). In one corner of the room, and as remote as possible from the control table, are four phones, at each of which a clerk takes down incoming warden reports.

(5) An alternate control center has been developed at fire headquarters. This location was chosen because it has an independent telephone system. In the alternate control room are deputies of the officers in the main control room.

j. Air-raid warning system. Four 2-horsepower rotary electric sirens have been erected in the camp to be used only for air-raid alarms. Only two alarms are given: the blue by sounding the sirens at the same pitch for 2 minutes and the red by sounding them at an alternating, fluctuating, or warbling pitch for 2 minutes. The sirens have been so installed that all four can be sounded simultaneously by the telephone operator at the main telephone exchange in post headquarters.

SECTION III
FIRE-DEFENSE AND PASSIVE-DEFENSE— MINIMUM FACILITIES

153. GENERAL. The passive air-defense and fire-defense plans outlined in section II (pars. 150, 152) are for the ideal situation which might confront the fire-defense officer of a major base. In active theater

of operations the problem of fire defense is of greater importance and is more difficult to solve. Shipping space and other limitations reduce the number of fire-fighting units available to cope with increased requirements caused by dispersion of installations, enemy aerial bombing, and frequent changes in location in a fast-moving situation. Losses in equipment and personnel must be expected and methods of filling gaps in the fire defense must be made a part of the passive air-defense plan. The fire-defense officer must be thoroughly familiar with the plans of the tactical commander in order to be able to make recommendations for maximum protection when and where it is needed.

154. UTILITIES. a. Water supply. An enemy retiring in good order will systematically destroy any public utilities of value to the fire defense of the locality. The passive air-defense plan must provide for other means of supplying water for fire-fighting equipment. Water sources may be developed from streams, lakes, or harbors, or from storage basins or cisterns in intermittent streams, road ditches, or basements of bombed-out buildings. The storage facilities of local water systems may be repaired temporarily and used as static sources of water for fire pumpers or tank-equipped apparatus. Covered sumps along the edges of the airfield runways provide auxiliary water for crash equipment. Canvas water tanks, tank trailers, and tank trucks of engineer aviation units are used for stand-by water storage.

b. Signal communications. Field telephone facilities and distinctive improvised fire alarms are the normal means of transmitting fire information in forward areas. Radio may be used if radio security permits. Messengers must be provided for use when normal means are disrupted by bombing. Fire observers in built-up areas or at air bases assist in spotting fires and report them by telephone to the control center.

155. PASSIVE AIR-DEFENSE PLANS. a. Passive air-defense plans in an active theater must be coordinated with and subordinate to active-defense plans. Fire-fighting sections are distributed over the area to be protected so that units are mutually supporting but still separated widely enough to prevent loss of more than one piece of equipment from a direct bomb hit. For planning purposes the distribution of fire-fighting units given in chapter 2 may be used. Fire-fighting units actually assigned to the establishment determine the final distribution on the ground.

b. Auxiliary fire-fighting personnel should be drawn from service-force units stationed at the base to be protected. Such troops are likely to remain in the area longer than ground-force units and, in addition, are better equipped and trained initially for operations of

this type. At airfields, ground crews and administrative personnel and engineer aviation units are a source of auxiliary personnel and equipment. Fire parties for local protection are organized in each tactical unit.

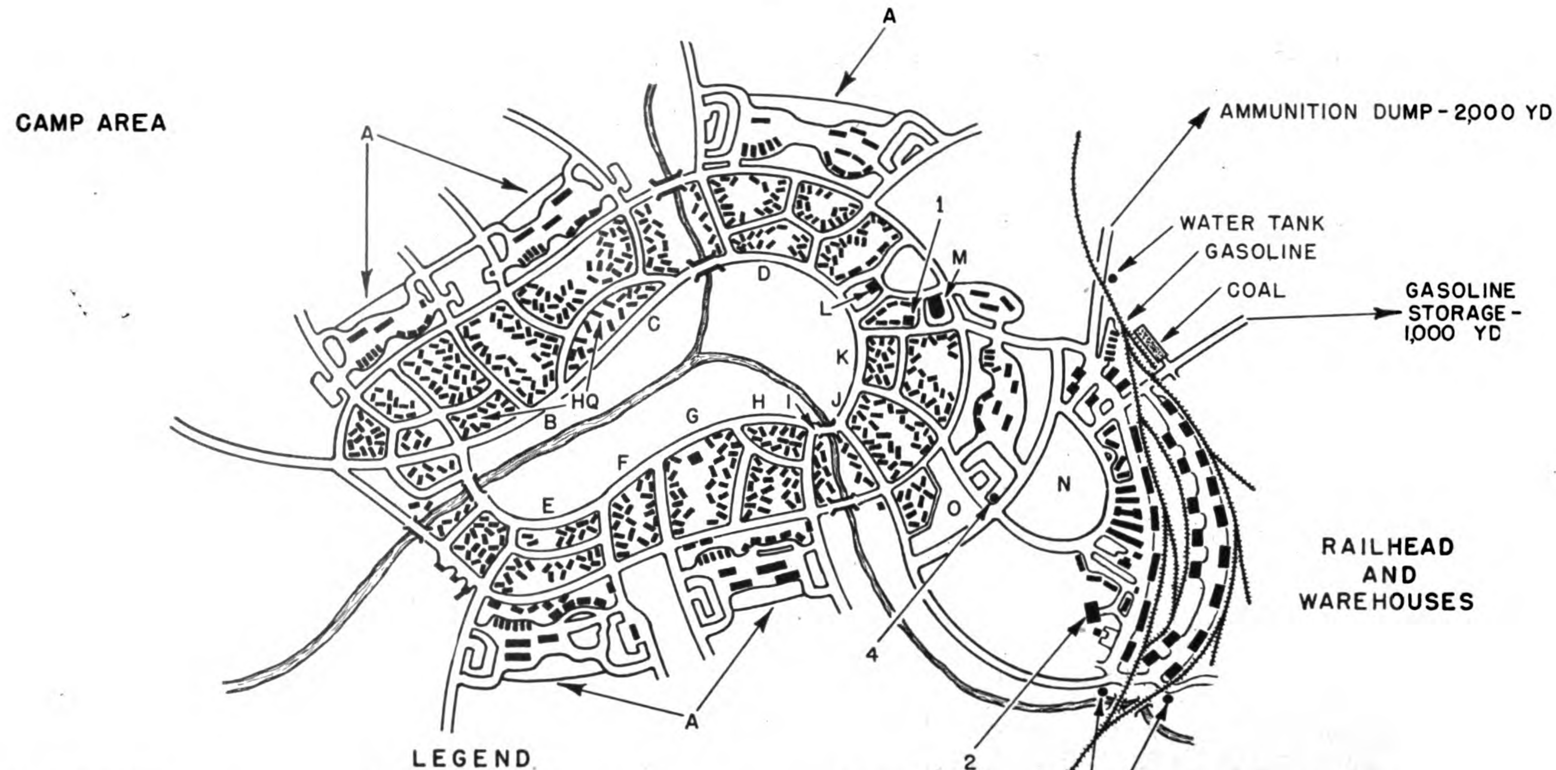
c. Ambulances of hospital units and transportation of other organizations are assigned to first-aid posts and collecting stations during air alerts to provide prompt removal of casualties to hospitals, or to points outside the affected area. Medical personnel are assigned to posts at hospitals or first-aid stations according to the plan of the senior surgeon. Medical detachments of tactical units are mobilized for first-aid work in their respective areas.

d. General engineer troops are organized for rescue work, demolition of unsafe structures, clearance of wreckage and maintenance, and repair of utilities and roads during and after air raids. Coordination of these activities with fire-fighting helps in controlling the spread of fires and in opening routes for the movement of fire-fighting equipment.

156. CONTROL OF PASSIVE AIR DEFENSE. Representatives of all services involved in the passive air defense and fire defense assemble at a designated control center to coordinate and direct the operations of units under their control and to insure a prompt, orderly resumption of normal activities at the end of the aerial attack.

157. SITUATION B—GROUND FORCE BASE. a. Description of Camp B (fig. 70). Camp B is located in the forward area of an active combat theater. It serves as a railhead and distributing point for class I, II, III, and IV supplies. Warehouse facilities consist of rebuilt civilian warehouses. Since this theater has been stabilized for some time, camp facilities have been improvised as a rest area for a combat division. The camp is situated on slightly rolling, well-wooded terrain. Two streams converge in the center of the camp and furnish the domestic water supply. The camp is well dispersed over a wide area and well camouflaged. Housing consists of tentage and a few portable wooden buildings. Temporary roads and bridges have been constructed to permit free access to divisional vehicles. Communication within the camp consists of field telephones with a switchboard located near division headquarters. Communication with higher headquarters and with the Army Information Center is by telephone and radio.

b. Passive air-defense organization for Camp B. (1) STANDING ORDERS. These orders provide for evacuation of troops and organizational vehicles to previously prepared dispersion areas away from the camp. Exceptions are the depot companies assigned to the warehouses and the railhead, the division engineer battalion, and the division quartermaster company.



LEGEND

A – MOTOR STORAGES
B – 1ST INFANTRY REGIMENT
C – 2ND INFANTRY REGIMENT
D – 3RD INFANTRY REGIMENT
E – DIVISION ARTILLERY
F – ORDNANCE COMPANY
G – QUARTERMASTER COMPANY
H – ENGINEER BATTALION
I – MEDICAL BATTALION
J – DIVISION TROOPS
K – POST TROOPS
L – DIVISION HEADQUARTERS
M – ARENA
N – WAREHOUSES AND UTILITIES
O – GUARD

1 – F F PLATOON HQ
2 – F F FIRST SECTION
3 – SKID PUMPS
4 – CONTROL CENTER

Figure 70. Advanced ground base.

(2) ENGINEERS. The division engineer battalion is dispersed over the camp area. Each company is assigned to one of the three divisional fire zones. Organizational pioneer tools and bulldozers are held in readiness for rapid construction of fire breaks around any portion of the camp affected. Back-pack pumps and pump-tank fire extinguishers have been provided in each regimental area.

(3) QUARTERMASTER TROOPS. The quartermaster company is assigned to the warehouse area to provide additional manpower. Depot companies assigned to the railhead and warehouse area are trained in incendiary bomb control and elementary fire fighting.

c. Fire protection. (1) NORMAL PROTECTION. Fire protection for Camp B and railhead area consists of one engineer fire-fighting platoon less two sections. Platoon headquarters and the headquarters section are located near division headquarters (1) (fig. 70). Section 1 is located near the railhead and warehouse area (2) (fig. 70).

(a) Normal fire protection for the camp area is furnished by the headquarters section. Since no water system or fire hydrants are available tent, grass, and forest fires are controlled by the use of the sections booster tank. Larger fires are controlled by hose lines. Suction is taken from previously prepared pumping stands located near the streams.

(b) Normal fire protection for the railhead and warehouse area is furnished by section No. 1. Water for the area is furnished from a 50,000-gallon water tank and gravity system. An electric-powered pump and well furnish the supply. Fire hydrants are located at 1,000-foot intervals along the line of warehouses. Pressure and main sizes are adequate for minimum protection.

(2) AUXILIARY PROTECTION. *(a)* Auxiliary skid pumps have been located permanently on the stream at (3) and (4) (fig. 70). Concrete wier boxes have been constructed to assure adequate suction facilities. Fixed piping arrangements have been made to pump directly into the water mains in case of failure of the pressure system caused by destruction of the water tank. Adequate roads allow trucks to lay hose lines from the pumps if the water mains are destroyed. Four auxiliary skid pumps are available to relay water to any portion of the area. They are stored in the utility warehouse in such a manner that they can be readily placed on trucks for mobile operation. Auxiliary fire hose is stored in the warehouse in previously prepared boxes, which also can be skidded onto trucks for immediate hose-laying operations to cover any portion of the warehouse area.

(b) Auxiliary fire-fighting equipment, consisting of hose carts, water buckets, and sand buckets, is located throughout the warehouse area. Auxiliary hand equipment for the use of the fire parties is placed in the warehouses.

(c) Auxiliary fire fighters and fire parties are organized from the personnel of the depot and division quartermaster companies. In addition to the personnel assigned to the skid pumps and as truck drivers and hose-laying crews, a fire party of four men is assigned to each warehouse.

(d) Messengers from the quartermaster company are on duty at division headquarters, at the fire station in the warehouse and utility area, and at the control center.

(e) A dressing station is maintained by the medical battalion in its own area. Litter bearers are strategically located throughout the camp and warehouse area for rapid evacuation of wounded.

(f) A decontamination station has been set up under the direction of the chemical officer in the vicinity of the warehouse and utility area.

(g) The control center is organized in a dugout at (5) (fig. 70) under the senior engineer officer.

(h) Field telephones and a switchboard connecting with all camp and railhead phones are provided in the control center. Radio communication is maintained with all radio-equipped units.

(i) In addition to the coordinator, the officer commanding the engineer fire-fighting platoon, the provost marshal, the surgeon, the chemical officer, the signal officer, and the transportation officer, or their representatives, are present in the control center.

d. Air raid alarms. Upon receipt of the blue alert from the Army Information Center, the commanding officer orders evacuation of tactical troops as previously described. Units held back to undertake passive defense take their stations. Since the camp area proper presents little of tactical value to the enemy, most of the effort will be directed toward defense of the railhead and warehouse area. Aided by the headquarters section of the engineer fire-fighting platoon, the division engineer battalion combats with organizational equipment all grass and forest fires started in the camp area. This section may be withdrawn from the camp area and ordered to the warehouse area if deemed necessary by the engineer fire fighting platoon commander.

158. SITUATION C—COMMUNICATION ZONE AIR BASE.

a. Description of Air Base C (fig. 71). (1) Air Base C is in an active theater of operations and has been bombed heavily in the past. Normally an air group operates from it, but during periods of intense air operations it is an auxiliary field for other aircraft. Bombers are parked on hard standings dispersed along the runways.

(2) The base is on fairly level ground with some natural cover. There are permanent buildings for administration, shop, and hospital purposes. Semipermanent and temporary buildings provide housing and other services. Gasoline and ammunition are delivered by rail. There

are no warehouses at the railroad. All installations are camouflaged and every advantage is taken of natural cover and concealment.

(3) Communications in the building area consist of a civilian telephone system with a switchboard in the main administration building: field telephones and runners are used in the airplane dispersal areas. The crash truck and crash trailers are equipped with radio receivers tuned to the band used by aircraft. Communication with higher headquarters and the Army Information Service is by telephone and radio.

b. Passive air-defense organization. (1) STANDING ORDERS. Standing orders provide that all personnel assigned to the base, except those engaged in active defense, be organized for passive defense. Training in incendiary bomb control and elementary fire fighting is given by the engineer aviation fire-fighting platoon.

(2) FIRE DEFENSE. Normal fire defense is furnished by one engineer aviation fire fighting platoon. Platoon headquarters is in the fire station (A). Headquarters section normally is located near the control tower (B) during flying operations. Two sections are distributed along the main runways to cover take-offs and landings. They are moved to other runways upon order from the control tower or from the platoon commander. The third section furnishes fire protection for ground installations from a fire station (C). An adequate water system supplies the ground installations. No water is available for fire fighting in the plane dispersal and bivouac areas. There are no natural streams near the base.

(3) AUXILIARY FIRE-FIGHTING EQUIPMENT. An auxiliary skid-mounted pump is connected permanently to the water system in the hospital area. Other skid-mounted pumps are located to pump from wells near the gasoline, bomb, and ammunition storage areas. One additional pump is stored in the engineer utility warehouse. It can be skidded into a 2½-ton truck for mobile operations. Auxiliary fire hose is provided by two 500-foot hose reels each in the hospital area, the gasoline and bomb storage area, and the shop and administration building area, and by hose stored in the utility warehouse. Hand fire-fighting equipment is located in all buildings for the fire parties.

(4) AUXILIARY WATER SUPPLIES. Cisterns within 500 feet of the important buildings in the hospital area provide a supply of water if the water system fails. All cisterns are masonry with covered tops, and are well camouflaged. Auxiliary water supply for crash trucks is provided by converted decontaminators M1 and M4, each of which carries 450 gallons. One is located near the control tower and the other in the main shop area. The road sprinkler truck also hauls water. Cisterns provide water in the airplane dispersal area.

(5) MEDICAL. A dressing station in a camouflaged area away from the hospital is maintained by the base surgeon. Litter bearers and

Figure 71. Major air base—zone of communications.

ambulances in protected locations near the control center are available on call.

(6) CHEMICAL. A decontamination station is located near the officers' quarters.

(7) CONTROL CENTER. The control center is in a camouflaged, reinforced concrete room (D). Operations are coordinated by the senior engineer officer. Officers commanding the passive defense services report to the control center when alerted. The control center has field-telephone and switchboard connections with all base facilities. Messengers are assigned to the control center, base headquarters, hospital, and to each control tower.

c. Dispersal of fire-fighting equipment. Upon a blue alert, the crash trailers in the two crash fire-fighting sections go to sandbag revetments with their equipment. Other personnel take cover in nearby foxholes. The sections leave the protection of the revetments to extinguish fires. The third section is held in reserve in the building area.

159. SITUATION D—ADVANCED AIR BASE. a. Description of advanced Air Base F (fig. 72). (1) Air Base D is an advanced base on an island near an active combat zone. It has been developed recently as a base following the island's capture. Two landing strips using steel planks have been developed.

(2) The base is situated in a small valley well-drained by two natural streams, and thickly covered with natural growth. No permanent buildings or facilities other than the landing strips have been built. Bivouac areas are adjacent to the plane dispersal areas. Repair facilities are in tents under cover of trees and foliage. Headquarters is in tents and native huts. Supply is accomplished from a beachhead about 2 miles away. Temporary roads and bridges connect the base with the beachhead. All installations other than landing strips and roads have been well camouflaged.

(3) Communication is by field telephone with a switchboard near base headquarters. Control towers are in trees near the landing strips. Communication with higher headquarters is by plane courier and radio. Air-raid warning service is supplied by radar.

b. Passive air-defense organization for Air Base D. (1) STANDING ORDERS. Since most problems arising out of enemy air attack concern active defense, little formal passive air-defense organization is required. However, personnel not otherwise engaged with active defense or with landing strip repairs is organized for the auxiliary fire protection of the beachhead and supply dump areas. This personnel has been given instruction by the engineer fire fighting sections in fire fighting and the removal of combustibles and explosives.

(2) FIRE. Since the fire protection problem is confined mostly to fires in parked aircraft and in food, ammunition, and gasoline supply dumps, and to protection of aircraft against crash fires, a complete engineer aviation fire-fighting platoon is not required. Accordingly, two sections have been detached from a platoon and have been flown to the base. Equipment consists of two class 1,010 crash trailers with tools, fire extinguishers, and a supply of liquid foam. Weapon carriers to pull the trailers have been delivered previously by landing boats.
(3) AUXILIARY SKID PUMPS. Two auxiliary skid pumps are in the vicinity of the gasoline storage area and two are in the vicinity of the ammunition and bomb storage area. Suction has been provided by wier boxes in nearby streams. Two skid pumps have been mounted on 2½-ton trucks for mobile fire-fighting operations at the beachhead. Sumps have been dug at intervals along the beach to provide suction at low tide.
(4) AUXILIARY FIRE-FIGHTING EQUIPMENT. Auxiliary equipment consists of 500-foot hose reel carts to cover the supply dump areas and auxiliary fire hose stored in skid boxes for operations at the beachhead.
(5) AUXILIARY FIRE FIGHTERS. Auxiliary firemen man the auxiliary fire pumps and hose lines upon receipt of a blue alert.
(6) AUXILIARY WATER SUPPLIES. Water for the crash trailers is stored in cisterns in the airplane dispersal areas. Arrangements have been made to employ water carts to haul additional water onto the runways to replenish booster tanks during crash fires.
(7) MESSENGERS. Messengers are assigned to base headquarters, to each control tower, and to the beachhead during landing operations.
(8) CHEMICAL. Decontamination stations under the base chemical officer have been set up near the operations and engineering tents adjacent to each landing strip.
(9) CONTROL CENTER. The senior engineer officer acts as fire marshal. Switchboard facilities and runners have been provided for him in a dugout near base headquarters.
(10) COMMUNICATIONS. The use of radio except for communication with aircraft has been banned during air raids. Communication between the radar unit and headquarters is by field telephone.

c. Air raid alarms. (1) Upon receipt of a yellow alert from the radar unit a prearranged signal of one round is fired from a fieldpiece located near headquarters.
(2) The signal for a blue alert is two rounds fired from the same gun. Upon receipt of this signal all active- and passive-defense personnel take their appointed stations. The airborne engineer aviation battalion prepares to make immediate repairs to the landing strips. Each

section of the engineer aviation fire-fighting platoon goes to revetments at "A" and "B" (fig. 71), respectively, for the protection of parked aircraft. Auxiliary fire fighters man the pumps and hose reels in the supply dumps.

(3) Should the alert occur during landing operations at the beachhead, arrangements have been made to dispatch one fire-fighting section to the beachhead to augment and direct the efforts of the auxiliary fire fighters assigned there.

(4) The two fire-fighting sections may be dispatched or employed at any point on the base or at the beachhead as necessity requires in the judgment of the officer or noncommissioned officer in command of the sections.

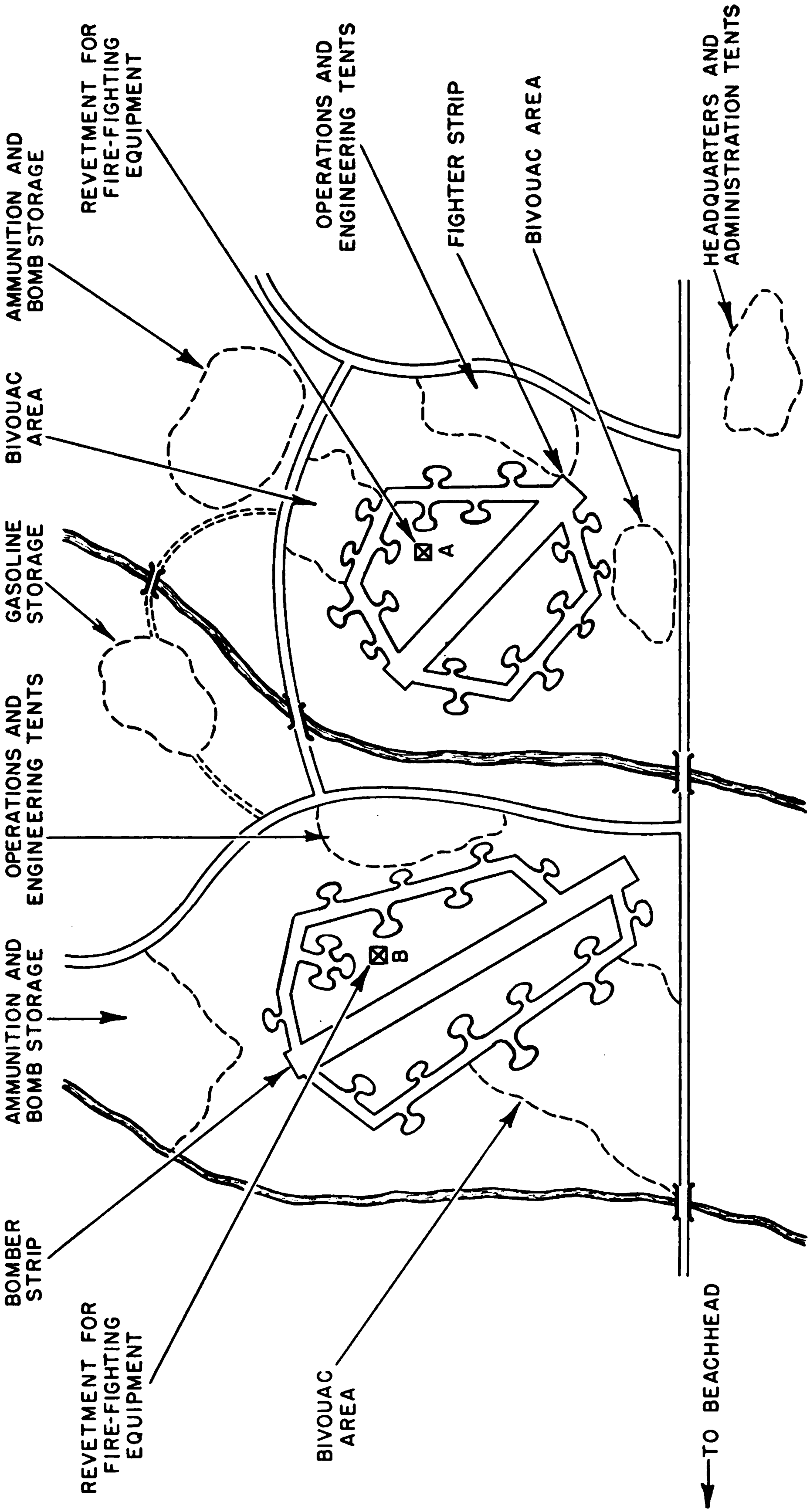


Figure 72. Advanced air base—combat zone.

Appendix I
LIST OF REFERENCES

1. ARMY REGULATIONS.

Transportation by Water of Explosives, Inflammables, and Chemical Materials	AR 55–470
Care and Use of Gasoline on War Department Vessels	AR 55–525
Storage and Issue	AR 700–10
Military Motor Vehicles	AR 850–15
Precautions in Handling Gasoline	AR 850–20
Compressed Gas Cylinders; Safe Handling, Storing, Shipping, Using	AR 850–60
Storage and Handling of Nitrocellulose Film in United States Army Establishments	AR 850–65

2. CORPS OF ENGINEERS PUBLICATIONS.

a. Repairs and Utilities Manual:

Fire Protection	Part VII, Chapter II
Water Supply	Part VII, Chapter V

b. O.C.E. Engineering Manual:

Water Supply Distribution and Storage	Chapter VI
Motor Fuel and Motor Oil Storage	Chapter VII
Fire Prevention	Chapter XVII

c. Miscellaneous:

Equipment Manual for Area and Post Engineers Fire Fighting Equipment	Chapter VI

3. ARMY AIR FORCES PUBLICATIONS.

a. Technical Orders:

Procedure to be Followed in Case of Fires During Flight	00–25–5
Equipment, Emergency for Field Ambulances	00–30–3
Kit, Crash Tools and Equipment, Ground	00–30–44
Fire Extinguishers—Installation and Inspection, 1-qt. Pump Type	03–45–1
Instructions and Parts Catalogue, Type A–2 Fire Extinguisher	03–45B–1
Aircraft Fire Extinguisher (CO_2) Type A–11–A–12–A–13 (Installed Systems)	03–45C–1

b. Miscellaneous:

4. MISCELLANEOUS.

Appendix II
LISTS OF EQUIPMENT

1. FIRE-FIGHTING EQUIPMENT—SET No. 1

Item	Unit	Quantity per set
Ax, wood-chopping	ea.	1
Battery, flashlight, dry cell	ea.	12
Carbon, tetrachloride, 5-gallon can	ea.	1
Charge, nonfreeze, 4-gallon, pump-tank	ea.	5
Door opener, clawbar, 1⅛ by 43⅛ inches	ea.	1
Extinguisher, fire, 4-gallon, pump-tank	ea.	1
Extinguisher, fire, 1-gallon, CTC	ea.	1
Flashlight, hand, 2-cell	ea.	2
Kit, first-aid, 24-unit	ea.	1
Rope, ¾-inch 50-foot coil	ea.	1
Shovel, round-point, short D-handle	ea.	2
Siren	ea.	1
Spotlight	ea.	2

2. FIRE-FIGHTING EQUIPMENT—SET No. 2

Item	Unit	Quantity per set
Ax, fire, pickhead	ea.	2
Battery, flashlight, dry-cell	ea.	30
Carbon tetrachloride, 5-gallon can	ea.	2
Charge, foam, pump-tank extinguisher	ea.	12
Charge, nonfreeze, 4-gallon pump-tank	ea.	25
Conversion unit, foam, pump-tank	ea.	2
Door opener, clawbar, 1⅛ by 43½ inches	ea.	1
Extinguisher, fire, 4-gallon, pump-tank	ea.	4
Extinguisher, fire, 1-gallon, CTC	ea.	2
Extinguisher, fire, 5-gallon, back-pack	ea.	2
Flashlight, hand, 2-cell	ea.	5
Kit, first-aid, 24-unit	ea.	1
Mattock, pick, 6-pound	ea.	2
Rope, ¾-inch, 100-foot coil	ea.	1
Rope, ¾-inch, 50-foot coil	ea.	1
Shovel, square-point, short D-handle	ea.	2
Shovel, round-point, long-handle	ea.	2
Siren	ea.	1
Spotlight	ea.	2

3. CLASS 325 FIRE TRUCK.

Item	Unit	Quantity per set
Adapter, 3 by 2½-inches	ea.	1
Adapter, ¾-inch I.P.T. female and ¾-inch garden H.T. male	ea.	2
Adapter, 2-inch I.P.T. female by 2½-inch N.S.T. male	ea.	2
Ax, fire, pickhead	ea.	2
Battery, flashlight, dry-cell	ea.	36
Battery, lantern, dry-cell	ea.	2
Bucket, galvanized	ea.	4
Carbon tetrachloride, 5-gallon can	ea.	1
Charge, foam-liquid, 2-gallon	ea.	25
Charge, foam, 4-gallon, pump	ea.	6
Charge, nonfreeze, 4-gallon, pump-tank	ea.	25
Clipper, bolt, ½-inch	ea.	1
Clipper, electric, insulated	ea.	1
Connection, double, female, 2½-inch	ea.	2
Connection, double, male, 2½-inch	ea.	2
Connection, siamese, gated 2½ by 1½ by 1½-inches	ea.	1
Conversion unit, foam, pump-tank	ea.	1
Door opener, clawbar, 1⅛ by 43⅛-inches	ea.	1
Expander, hose, hand, 2½-inch	ea.	1
Expander, hose, hand, 1½-inch	ea.	1
Expansion ring, hose, 2½-inch	ea.	60
Expansion ring, hose, 1½-inch	ea.	60
Extinguisher, fire, 4-gallon, pump-tank	ea.	3
Extinguisher, fire, 5-gallon, pack-back	ea.	2
Extinguisher, fire, 1-gallon, CTC	ea.	1
Flashlight, hand, 2-cell	ea.	6
Gasket, expansion-ring, hose, 2½-inch	ea.	60
Gasket, expansion-ring, hose, 1½-inch	ea.	60
Gasket, fire-hose, 2½-inch	ea.	60
Gasket, fire-hose, 1½-inch	ea.	50
Gasket, chemical-hose, 1-inch	ea.	25
Gasket, hose, garden, ¾-inch	ea.	25
Gloves, rubber and leather, lineman's w/box, container and talcum	ea.	1
Hose, suction, hard, 3-inch, 10-foot lengths	ea.	2
Hose, fire, 2½-inch, C.R.L., D.J., N.S.T.	ft.	1,200
Hose, fire, 1½-inch, C.R.L., D.J., N.S.T.	ft.	800
Hose, gasket, 3-inch		12
Hose, chemical, high-pressure, ¾-inch, rubber, 1-inch coupling	ft.	350
Hose, water, ¾-inch, braided	ft.	100
Kit, first-aid, 24-unit	ea.	1
Ladder, extension, 20-foot	ea.	1
Ladder, roof, 12-foot	ea.	1

3. CLASS 325 FIRE TRUCK—(Continued)

Item	Unit	Quantity per set
Lantern, hand, electric	ea.	2
Mattock, pick, 6-pounds	ea.	2
Nozzle, shut-off, 2½-inch, 1-inch tip	ea.	2
Nozzle, shut-off, 1½-inch, ½-inch tip, 1-inch thread	ea.	2
Nozzle, chemical, 1-inch	ea.	2
Nozzle, fog comb., 1½-inch, w/applicator	ea.	1
Nozzle, foam, 1-inch, with injector	ea.	2
Pike, pole, 10-foot	ea.	1
Rope, ¾-inch, 100-foot coil	ea.	1
Rope, ¾-inch, 50-foot coil	ea.	1
Shovel, round-point, long-handle	ea.	2
Shovel, square-point, short D-handle	ea.	2
Strainer, suction, 3-inch, with rope	ea.	1
Tarpaulin, 18 by 18 feet, with grommets	ea.	1
Wrench, hydrant, adjustable	ea.	2
Wrench, spanner, universal	ea.	6
Wrench, spanner, 1-inch, chemical	ea.	2

4. CLASS 125 OR 135 CRASH TRUCK.

Item	Unit	Quantity per set
Ax, fire, pickhead	ea.	1
Battery, flashlight, dry-cell	ea.	2
Bucket, galvanized	ea.	4
Carbon tetrachloride, 5-gallon can	ea.	1
Charge, foam-liquid, 2-gallon	ea.	100
Charge, foam, pump-tank-extinguisher	ea.	6
Clipper, electric, insulated	ea.	1
Connection, double female, 2½-inch	ea.	1
Conversion unit, foam, pump-tank	ea.	1
Crowbar, ¾ by 30-inches	ea.	1
Door opener, clawbar, 1⅛ by 4⅜-inches	ea.	1
Expander, hose, hand, 2½-inch	ea.	1
Expander, hose, hand, 1½-inch	ea.	1
Extinguisher, fire, 1-gallon CTC	ea.	1
Extinguisher, fire, 4-gallon, pump-tank	ea.	1
Extinguisher, fire, 15-pound, CO_2	ea.	2
Floodlight, dry-cell	ea.	1
Gasket, high-pressure, hose	ea.	25
Gasket, hose, garden, ¾-inch	ea.	25

4. CLASS 125 OR 135 CRASH TRUCK—(Continued)

Item	Unit	Quantity per set
Gloves, rubber and leather, lineman's w/box container and talcum	ea.	1
Gas, CO_2, 50-pound in cylinders	ea.	15
Grapnel and cable	ea.	1
Hose, high-pressure, ¾-inch	ft.	300
Hose, suction, hard, 2½-inch, 10-foot lengths	ea.	2
Hose, water, ¾-inch, braided	ft.	100
Kit, first-aid, 24-unit	ea.	1
Suit, asbestos	ea.	2
Kit, recharge, CO_2, bypass-type	ea.	1
Ladder, comb., folding, 16-foot	ea.	2
Nozzle, foam, 1-inch, with injector	ea.	2
Nozzle, water, ¾-inch	ea.	2
Nozzle, high-pressure-spray	ea.	2
Pike pole	ea.	1
Rope, ¾-inch, 100-feet coil	ea.	1
Roll, emergency-crash, complete with ax, chopping, single-bit, 4-pound	ea.	1
Bar, wrecking, carpenter, gooseneck, ¾ by 30-inches	ea.	1
Clipper, belt, ⅜-inch	ea.	1
Cutter, pipe, ⅛ to 2-inches	ea.	1
Extinguisher, 1-quart, CTC	ea.	1
Flashlight, 3-cell	ea.	2
Hacksaw, frame w/blades, type B, 12-inches long, 32-point	ea.	1
Knife, hunting	ea.	1
Pliers, side-cutting, 8-inch	ea.	1
Saw, cross-cut, type N, 24-inch	ea.	1
Shears, tinners'	ea.	1
Sledge, blacksmith, crosspeen, 6-pound	ea.	1
Wrench, hydrant, adjustable	ea.	2

5. CLASS 1,000 FIRE TRAILER.

Item	Unit	Quantity per set
Adapter, 4½ by 2½-inches	ea.	1
Adapter, ¾-inch I.P.T. female by 2½-inches garden H.T.	ea.	2
Adapter, 2-inches I.P.T. female by 2½-inches N.S.T. male	ea.	2
Ax, fire, pickhead	ea.	1
Battery, lantern, dry-cell	ea.	3
Charge, foam-liquid, 2-gallon	ea.	12

5. CLASS 1,000 FIRE TRAILER—(Continued)

Item	Unit	Quantity per set
Connection, double-female, 4½-inches	ea.	1
Connection, double-female, 2½-inches	ea.	2
Connection, double-male, 2½-inches	ea.	2
Connection, siamese, gated 2½ by 1½ by 1½-inches	ea.	1
Door opener, clawbar, 1½ by 43⅛-inches	ea.	1
Expansion ring, hose, 2½-inches	ea.	30
Expansion ring, hose, 1½-inches	ea.	30
Gasket, expansion-ring, hose, 2½-inches	ea.	30
Gasket, expansion-ring, hose, 1½-inches	ea.	30
Gasket, fire-hose, 2½-inches	ea.	30
Gasket, fire-hose, 1½-inches	ea.	50
Gasket, hose, rubber, 4½-inches	ea.	12
Hose, suction, hard, 4½-inches, 10-feet lengths	ea.	2
Hose, fire, 2½-inches, C.R.L., D.J., N.S.T.	ft.	1,250
Hose, fire, 1½-inches, C.R.L., D.J., N.S.T.	ft.	300
Lantern, hand, electric	ea.	2
Nozzle, shut-off, 2½-inches, 1-inch tip	ea.	2
Nozzle, shut-off, 1½-inches, ½-inch tip	ea.	2
Nozzle, fog, comb., 1½-inches, with applicator	ea.	1
Nozzle, foam, 1-inch, with injector	ea.	1
Spotlight	ea.	1
Strainer, suction, 4½-inches	ea.	1
Tarpaulin, 16 by 18-feet, w/grommets	ea.	1
Wrench, hydrant, adjustable	ea.	2
Wrench, spanner, universal	ea.	6
Wrench, spanner, 4½-inches	ea.	2

6. CLASS 1,010 OR CLASS 1,020 CRASH TRAILER.

Item	Unit	Quantity per set
Ax, fire, pickhead	ea.	1
Bucket, galvanized	ea.	4
Charge, foam liquid, 2-gallon	ea.	50
Connection, double-female, 2½-inches	ea.	1
Crowbar, ¾-inch by 30-inches	ea.	1
Door opener, clawbar, 1⅛ by 43⅛ inches	ea.	1
Extinguisher, fire, 15-pounds CO_2	ea.	1
Floodlight, wet-cell	ea.	1
Gasket, fire-hose, 2½-inches	ea.	20
Gasket hose, high-pressure, ¾-inch	ea.	25
Gasket, hose, garden, ¾-inch	ea.	25
Grapnel and cable	ea.	1

6. CLASS 1,010 OR CLASS 1,020 CRASH TRAILER—(Continued)

Item	Unit	Quantity per set
Hose, suction, hard, 2½-inches, 10-feet lengths	ea.	2
Hose, high-pressure, ¾-inch	ft.	200
Hose, water, ¾-inch, braided	ft.	100
Nozzle, foam, 1-inch, with injector	ea.	2
Nozzle, water, ¾-inch	ea.	2
Nozzle, high-pressure, spray	ea.	2
Roll, emergency-crash, complete with ax, chopping, single-bit, 4-pounds	ea.	1
Bar, wrecking, carpenter, gooseneck, ¾ by 30-inches	ea.	1
Clipper, bolt, ⅜-inch	ea.	1
Cutter, pipe, ⅛ to 2-inches	ea.	1
Extinguisher, 1-quart, CTC	ea.	1
Flashlight, 3-cell	ea.	2
Hacksaw, frame w/blades, type B, 12-inches long, 32-point	ea.	1
Knife, hunting	ea.	1
Pliers, side-cutting, 8-inches	ea.	1
Saw, crosscut, type N, 24-inches	ea.	1
Shears, tinners'	ea.	1
Sledge, blacksmith, crosspeen, 6-pounds	ea.	1
Spotlight	ea.	1
Strainer, suction, 2½-inches	ea.	1
Wrench, hydrant, adjustable	ea.	2

INDEX